THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

· AUGUST · 1915 ·

SAN FRANCISCO MEETING, SEPTEMBER 16-17

ANNUAL MEETING, NEW YORK CITY, DECEMBER 7-10

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MEMBERS of the Society should become better acquainted with the splendid library facilities they own and with the advantages which can be secured.

A Service Bureau has been inaugurated to bring closer to all members, no matter where located, the facilities of our complete technical Library.

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Over sixty thousand books on technical subjects and more than one thousand engineering or scientific periodicals are included in the treasures of the Library.

Members, who may desire it, will be kept posted on the current publication on any engineering subject.

When necessary to charge for service, it is at actual cost. The Library does not carry on work of a commercial nature.

All work done by the Service Bureau is strictly confidential.

A bibliography on any subject will be prepared and the volumes relating thereto set aside for the personal perusal of those members who are able to visit the Library.

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THE JOURNAL OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Volume 37 August 1915 Number 8

THE SEPTEMBER MEETING

AND

THE INTERNATIONAL ENGINEERING CONGRESS, 1915

THE centre of gravity of the engineering profession in September will be the International Engineering Congress to be held in San Francisco during the week of the twentieth, and for this reason the September meetings of the four national engineering societies have been arranged to take place in that city during the week preceding the Congress. Also, members of the societies attending the meeting and Congress will be afforded the unique opportunity of visiting the Panama-Pacific International Exposition at San Francisco, the Panama-California Exposition at San Diego, as well as some of this country's most famous points of scenic interest on the route from the east to the west.

The Committee on Local Affairs in San Francisco has placed its services at the disposal of all engineers resident within the United States, so that those who visit San Francisco with their families and friends may be sure that special attention will be paid to their comfort.

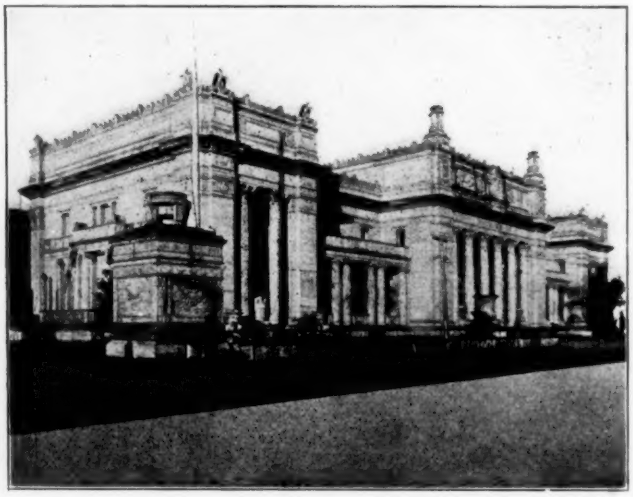
THE JOURNEY TO SAN FRANCISCO

Arrangements have been made for a special train for members of the Society and their friends, leaving New York (Grand Central Terminal) on Thursday, September 9, at 7.45 P.M. The train will stop at Niagara Falls for four hours on Friday morning, allowing time for the members of the party who so desire to take the famous Niagara Gorge Trip. On Sunday morning the party will arrive at Colorado Springs, where members will be enabled to tour Crystal Park and also journey to Pike's Peak, Garden of the Gods, Cheyenne Canyon and the Seven Falls. The Grand Canyon will be reached on Tuesday morning and fifteen hours will be spent there, which is ample time for excursions to Bright Angel Trail, Bottom of Canyon, Hopi Point, Hermit Rim Drive and Sunset Point. The party will arrive at San Francisco on Wednesday, September 15, at 9 A.M.

TOWER OF JEWELS
PANAMA-PACIFIC EXPOSITION

Reservations for this train are now being arranged by Mr. G. S. Harner, Passenger Agent, New York Central Lines, 1216 Broadway, New York City, and to secure desirable accommodations applications should be addressed directly to Mr. Harner as early as possible, mentioning the Society. The fare to San Francisco by this train and return by any route (except via Northwestern points) is \$98.80. Pullman rates, one way: \$22.00, lower berth; \$17.60, upper berth.

For those members of the Society who cannot join the party from New York, reservations are being made on the Sunset Limited, leaving New Orleans on Sunday, September 12, at 11 A.M., and arriving in San Francisco at 1.00 P.M. on Wednesday, September 15. Accommodations on this train can now be secured by addressing Mr. J. H. R. Parsons, General Passenger Agent, Southern Pacific Company, New Orleans, La. The round trip fare, New Orleans to San Francisco, is \$57.50 going and



New York State Building

Avenue of Progress

returning over the same route, or \$62.50 returning to Chicago. Pullman rates, one way: \$11.50, lower berth; \$9.20, upper berth.

THE SEPTEMBER MEETING

The professional sessions of the September meeting of the Society will be held in the Hall of the Native Sons of the Golden West, Mason Street, between Geary and Post, San Francisco, on the mornings of Thursday, September 16, and Friday, September 17. While the program has not been fully completed, it can be stated that there will be papers on Thursday morning treating comprehensively of the exhibits and the engineering features of the Panama-Pacific International Exposition, and on Friday there will be papers and discussion on the subject of the oil engine with special reference to its use with California oils.

HEADQUARTERS IN SAN FRANCISCO

The headquarters of the Society will be the Clift Hotel, at the corner of Geary and Taylor Streets, San Francisco. For members who desire to be accommodated at this hotel, a number of rooms have been arranged for. The rate is \$5.50 for each room, to be occupied by one or two persons, and to include bath. Each member should make his own reservation direct with the hotel, mentioning the Society.

For convenience, the rates at other hotels as quoted to the Society are given below:

Palace Hotel, Market and New Montgomery Streets, \$4.00 per day, room and bath, one person.

Fairmont Hotel, California and Mason Streets, \$4.00 per day, room and bath, one person.

Hotel St. Francis, Geary and Powell Streets, \$7.00 per day up, room and bath, two persons.

Hotel St. Regis, 83 Fourth Street, \$2.50 per day up, room and bath, two persons.

Information regarding accommodations at any other hotels may be obtained by addressing the Official Exposition Hotel Bureau, 702 Market Street, San Fran-

Varied Industries and Mines

Court of Four Seasons

PALACE OF EDUCATION

COLUMN OF PROGRESS

cisco. This Bureau also undertakes to make reservations in approved hotels without charge.

MEETINGS OF OTHER SOCIETIES

The American Society of Civil Engineers, the American Institute of Mining Engineers, and the American Institute of Electrical Engineers will also hold September meetings in San Francisco on the days preceding the Congress.

The headquarters of these societies and their places of meeting are listed below:

Society	*Headquarters*	*Meetings*
A. S. C. E.	St. Francis Hotel	Same
A. I. M. E.	Hotel Bellevue	Same
A. I. E. E.	St. Francis Hotel	Civil Center Auditorium

The meeting of the American Society of Civil Engineers is the Forty-seventh Annual Convention of the Society. The programme includes a welcoming address by President Charles D. Marx; a Panama Canal session; a reception, dinner and dance in the Old Faithful Inn on the grounds of the Panama-Pacific International Exposition, and excursions to Del Monte, Santa Cruz and San José. The Society, through its Secretary, Chas. Warren Hunt, has extended a cordial invitation to the membership of our Society to participate in these events. The dates of this convention are September 16 to 18.

INTERNATIONAL ENGINEERING CONGRESS, 1915

The holding of a Congress of Engineers from the great associations of the world on the scene of the celebration of the completion of the Panama Canal was conceived as far back as 1912. In February of that year a convention of engineering societies was held in San Francisco, and as the outcome of the recommendations there made the International Engineering Congress, 1915, was organized.

Indefatigable have been the efforts of the Committee of Management of the Congress to secure the success

PALACE OF MANUFACTURES

COLONNADES, COURT OF FOUR SEASONS

of the enterprise by the coöperation of members from the national engineering societies. The last report of this committee announced that practically three thousand members had been enrolled and almost two hundred papers had been received.

The Congress will publish ten volumes of proceedings on the following topics: The Panama Canal; Waterways, Irrigation; Municipal Engineering; Railways, Railway Engineering; Materials of Engineering Construction; Mechanical Engineering; Electrical Engineering, Mechanical Engineering; Mining Engineering, Metallurgy; Naval Architecture and Marine Engineering; miscellaneous, including Military Engineering, Aeronautical Engineering, and Heating and Ventilation.

Members of the Society still have an opportunity of enrolling in the Congress if they wish to do so. The fee is nominal, five dollars, and entitles the subscriber to a certificate of membership, to participation in the deliberations of the Congress, to an index volume of the proceedings, and to one of the volumes listed above. Remittances may be made to Mr. W. A. Cattell, Secretary, Foxcroft Building, San Francisco.

The Congress will be opened at 10 A.M. on Monday, September 20, in the new Auditorium Building, where the subsequent sessions will be held. At the opening session there will be addresses of welcome and responses, an address by General George W. Goethals, Honorary President, and the presentation of the John Fritz Medal to Dr. James Douglas. The second session will be devoted to the Panama Canal, and sessions on the topics mentioned above will follow through the week.

EXCURSIONS IN AND AROUND SAN FRANCISCO

For the benefit of members visiting San Francisco for the September meeting and the Congress, the following excursions to important engineering activities in California have been arranged. Some of these will be by automobile without expense, and others will only entail the cost of a round trip ticket.

September 18: San Francisco High Pressure Fire System.
Portrero Gas Works Electric Station A, Pacific Gas & Electric Co.
Spring Valley Water Works.

September 19: Delta Lands of the Sacramento and San Joaquin Rivers.
Spring Valley Water Works.

September 17 to 18: Great Western Power Company's Hydroelectric development on the Feather River.
Gold dredging at Oroville.

September 18 to 19: Pacific Gas & Electric Co.'s Hydroelectric development at Lake Spaulding and Drum Power House.
North Star & Empire Mines at Grass Valley.

September 17 to 19: Oil fields at Coalinga.

THE PANAMA-PACIFIC INTERNATIONAL EXPOSITION

Of the eleven main exhibit palaces of the Exposition, some of which are here illustrated, those of particular interest to the members of the Society will be the Manufactures and Varied Interests Building; the Machinery Building; the Mines and Metallurgy Building, and the Education Building.

The great palace of Machinery is the largest on the Exposition site and is nearly a thousand feet in length. In this palace numerous groups comprising examples of steam generators and motors, internal combustion motors, hydraulic motors, and wood and metal working tools are shown.

The exhibits in the palace of Mines and Metallurgy deal with the natural mineral resources of the world, their conversion into metal and manufacture in raw materials and forms for the various industries.

Education is represented by examples including methods of vocational training and municipal training, in addition to general educational work of schools and universities.

The Manufactures and Varied Industries palace contains products of manufacture and manual skill from all nations of the world.

THE PANAMA-CALIFORNIA EXPOSITION

Now being held at San Diego, California, this is also within easy reach of those visiting the Pacific Coast. This Exposition is also in commemoration of the opening of the Panama Canal, but its theme is the exploitation of the possibilities and opportunities of the various sections of this coast, from Alaska to Peru.

The Exposition is staged in Balboa Park, in the heart of the city of San Diego, and its exhibits are grouped in an educational and attractive manner in twelve buildings.

THE RETURN FROM SAN FRANCISCO

Members of the party journeying to San Francisco by the Engineers' Special have the privilege of returning by one of several routes, of which the following are examples:

Via Southern Pacific or Western Pacific to Ogden and Salt Lake City, over the Rocky Mountains to Denver or Cheyenne, thence via Chicago or St. Louis.

Via Los Angeles, San Pedro Route to Salt Lake City, and thence as above.

Via Los Angeles, the Santa Fé Route through Albuquerque (also Denver if desired) to Chicago.

Via Los Angeles, El Paso and the Rock Island Route to Chicago.

Via Los Angeles and El Paso to New Orleans, thence via St. Louis, Chicago or Cincinnati.

Via Portland, Tacoma, or Seattle, thence via Ogden and Salt Lake City and the Rocky Mountains to Cheyenne or Denver, and Chicago or St. Louis.

Via Portland, Tacoma and Seattle to St. Paul, thence via Chicago.

Via Portland and Tacoma to Seattle, steamer or rail to Vancouver, thence via the Canadian Rockies, Winnipeg and St. Paul to Chicago.

Mr. Harner, the New York Central Lines agent, will quote any member the rates for return by any of the above or any other routes.

NAVY ADVISORY BOARD

Following the announcement in the daily papers of the organization of an Advisory Board for the U. S. Navy, of which Thomas A. Edison is Chairman, the Society received an invitation from the Honorable Josephus Daniels, the Secretary of the Navy, asking the appointment of two members to serve on the Board.

Similar invitations have been extended to several other scientific and engineering societies, with a view to having the Board representative of the most advanced thought and experience in the various lines of engineering activity and scientific research.

Inasmuch as there will be no regular meeting of the Council until October, the Executive Committee of the Council took the matter under consideration and have arranged for a ballot by the Council by which means it is expected that an early selection of representatives will be made. It is the desire that the appointees to the Advisory Board should be distinctly representative of the mechanical engineers of the country and the aim will be to select men of foresight and executive ability in combination with inventive talent.

JOINT COMMITTEE ON STANDARDS FOR GRAPHIC PRESENTATION

PRELIMINARY REPORT PUBLISHED FOR THE PURPOSE OF INVITING SUGGESTIONS FOR THE BENEFIT OF THE COMMITTEE[1]

As a result of invitations extended by The American Society of Mechanical Engineers, a number of associations of national scope have appointed representatives on a Joint Committee on Standards for Graphic Presentation. Below are the names of the members of the committee and of the associations which have coöperated in its formation.

Willard C. Brinton, *Chairman*, American Society of Mechanical Engineers. [7 East 42nd Street, New York City.]

Leonard P. Ayres, *Secretary*, American Statistical Association. [130 East 22nd Street, New York City.]

N. A. Carle, American Institute of Electrical Engineers.

Robert E. Chaddock, American Association for the Advancement of Science.

Frederick A. Cleveland, American Academy of Political and Social Science.

H. E. Crampton, American Genetic Association.

Walter S. Gifford, American Economic Association.

J. Arthur Harris, American Society of Naturalists.

H. E. Hawkes, American Mathematical Society.

Joseph A. Hill, United States Census Bureau.

Henry D. Hubbard, United States Bureau of Standards.

Robert H. Montgomery, American Association of Public Accountants.

Henry H. Norris, Society for the Promotion of Engineering Education.

Alexander Smith, American Chemical Society.

Judd Stewart, American Institute of Mining Engineers.

Wendall M. Strong, Actuarial Society of America.

Edward L. Thorndike, American Psychological Association.

The committee is making a study of the methods used in different fields of endeavor for presenting statistical and quantitative data in graphic form. As civilization advances there is being brought to the attention of the average individual a constantly increasing volume of comparative figures and general data of a scientific, technical and statistical nature. The graphic method permits the presentation of such figures and data with a great saving of time and also with more clearness than would otherwise be obtained. If simple and convenient standards can be found and made generally known, there will be possible a more universal use of graphic methods with a consequent gain to mankind because of the greater speed and accuracy with which complex information may be imparted and interpreted.

THE FOLLOWING ARE SUGGESTIONS WHICH THE COMMITTEE HAS THUS FAR CONSIDERED AS REPRESENTING THE MORE GENERALLY APPLICABLE PRINCIPLES OF ELEMENTARY GRAPHIC PRESENTATION

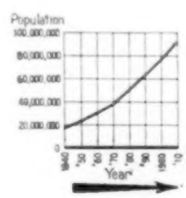


Fig. 1

1. The general arrangement of a diagram should proceed from left to right.

Fig. 2

2. Where possible represent quantities by linear magnitudes as areas or volumes are more likely to be misinterpreted.

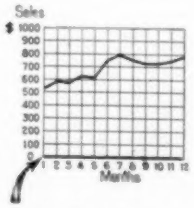


Fig. 3

3. For a curve the vertical scale, whenever practicable, should be so selected that the zero line will appear on the diagram.

[1] Copies may be had from The American Society of Mechanical Engineers, 29 West 39th St., New York: 5 cents to members; 10 cents to non-members.

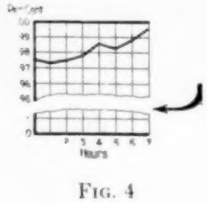


FIG. 4

4. If the zero line of the vertical scale will not normally appear on the curve diagram, the zero line should be shown by the use of a horizontal break in the diagram.

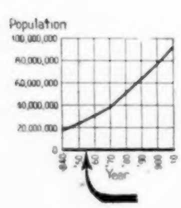


FIG. 5A

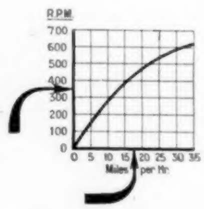


FIG. 5B

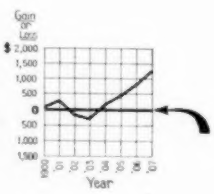


FIG. 5C

5. The zero lines of the scales for a curve should be sharply distinguished from the other coördinate lines.

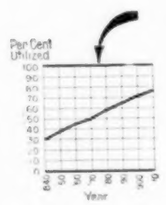


FIG. 6A

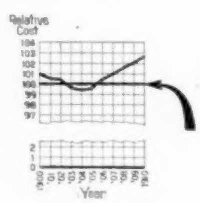


FIG. 6B

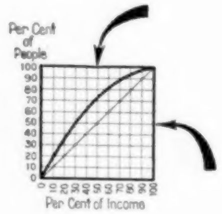


FIG. 6C

6. For curves having a scale representing percentages, it is usually desirable to emphasize in some distinctive way the 100 per cent line or other line used as a basis of comparison.

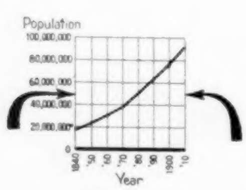


FIG. 7

7. When the scale of a diagram refers to dates, and the period represented is not a complete unit, it is better not to emphasize the first and last ordinates, since such a diagram does not represent the beginning or end of time.

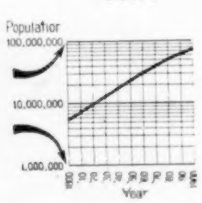


FIG. 8

8. When curves are drawn on logarithmic coördinates, the limiting lines of the diagram should each be at some power of ten on the logarithmic scales.

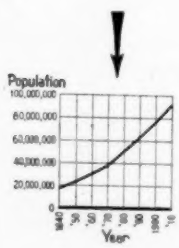


FIG. 9A

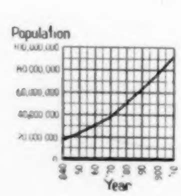


FIG. 9B

9. It is advisable not to show any more coördinate lines than necessary to guide the eye in reading the diagram.

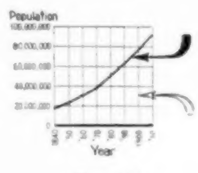


FIG. 10

10. The curve lines of a diagram should be sharply distinguished from the ruling.

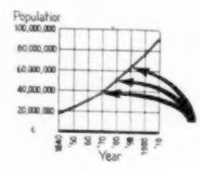


FIG. 11A

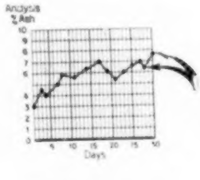


FIG. 11B

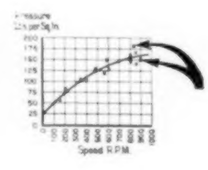


FIG. 11C

11. In curves representing a series of observations, it is advisable, whenever possible, to indicate clearly on the diagram all the points representing the separate observations.

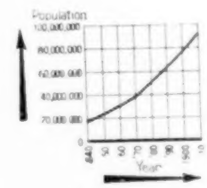


FIG. 12

12. The horizontal scale for curves should usually read from left to right and the vertical scale from bottom to top.

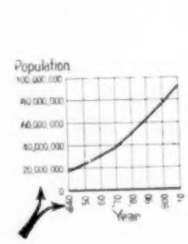


FIG. 13A

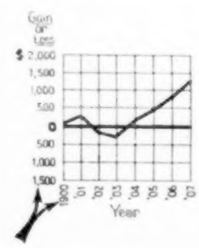


FIG. 13B

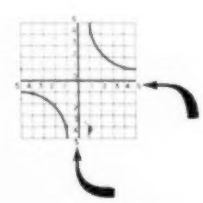


FIG. 13C

13. Figures for the scales of a diagram should be placed at the left and at the bottom or along the respective axes.

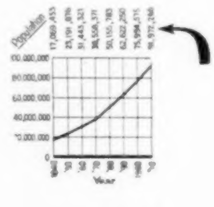


FIG. 14A

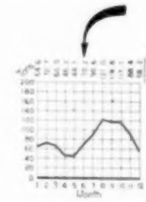


FIG. 14B

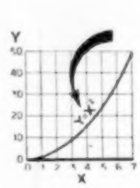


FIG. 14C

14. It is often desirable to include in the diagram the numerical data or formulae represented.

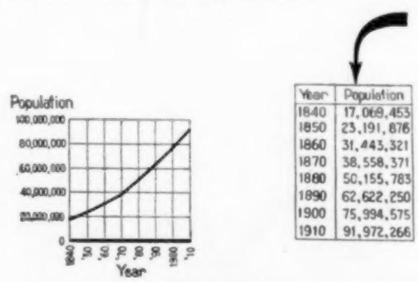


FIG. 15

15. If numerical data are not included in the diagram it is desirable to give the data in tabular form accompanying the diagram.

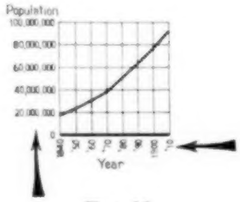
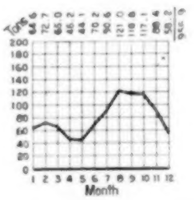


Fig. 16

16. All lettering and all figures on a diagram should be placed so as to be easily read from the base a° the bottom, or from the right-hand edge of the diagram as the bottom.



Aluminum Castings Output of Plant No. 2, by Months, 1914
Output is given in short tons
Sales of scrap aluminum are not included
Fig. 17

17. The title of a diagram should be made as clear and complete as possible. Sub-titles or descriptions should be added if necessary to insure clearness.

LIBRARY SERVICE BUREAU

With a view to bringing closer to members the facilities and usefulness of our splendid technical library, the Library Board has inaugurated a Service Bureau whose duty it will be to maintain a staff of expert searchers and translators to insure prompt and thoroughly efficient service to those members who live at such distance from New York as to make it inconvenient for them to consult personally the books and periodicals, and to those New York members who desire to avail themselves of this service.

Members who desire to be kept posted on the current publications of any engineering subject may receive such service by signing a form which states:

I hereby subscribe $10.00 for Library Service for one year from date with the understanding that the subscription shall apply on service which I may request with reference to the following:
- Reference cards
- Translating
- Copying
- Bibliographing
- Abstracting
- Searches for patent purposes
- Statistical searches and reports

The Library is not permitted to carry on any work of a commercial character and, therefore, the prices charged members for service are kept down to a merely self-supporting basis. For the purpose of economic administration the subscription feature previously referred to has been established.

Forms have been prepared for the use of those desiring to receive regular service which give the schedule of charges for the different classes of service.

All the work done by the Library Service Bureau is strictly confidential, and this feature is especially important in relation to searches made for patent purposes.

At present there are in the Library over sixty thousand volumes on technical subjects, and there are received currently over one thousand engineering or scientific periodicals. In addition, the searchers have ready access to the New York Public Library and the Library of the Chemists Club.

For those members who are personally able to use the library a bibliography on any subject will, on request, be prepared by the Bureau, and with adequate prior notice, the volumes relating thereto will be set apart for personal perusal.

It is desired that all members shall become better acquainted with the facilities of the splendid library they own, and with the advantages which can be secured by those who avail themselves of the aid furnished by its Service Bureau.

APPLICATIONS FOR MEMBERSHIP

TO BE VOTED FOR ON SEPTEMBER 10, 1915

Members are requested to scrutinize with the utmost care the following list of candidates who have filed applications for membership in the Society. These are sub-divided according to the grades for which their ages would qualify them and not with regard to professional qualifications, i. e., the ages of those under the first heading would place them under either Member, Associate or Associate-Member, those in the next class under Associate-Member or Junior, while those in the third class are qualified for Junior grade only. Applications for change of grading are also posted.

The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into the Society by advising the Secretary promptly of any one whose eligibility for membership is in any way questioned. All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote. These candidates will be balloted upon by the Council unless objection is received before September 10, 1915.

NEW APPLICATIONS

FOR CONSIDERATION AS MEMBER, ASSOCIATE OR ASSOCIATE-MEMBER

Annis, Lawrence F., Supt. of Constr., Southwark Fdy. & Mch. Co., Philadelphia, Pa.

Atkinson, Herbert S., Prod. and Designing Engr., Clam Shell Bucket Dept., The Hayward Co., New York.

Bell, Paul J., Mgr., San Carlos Milling Co., Ltd., San Carlos, Philippine Islands.

Bennett, Charles F., Supt., Standard Plunger Elev. Co., Worcester, Mass.

CUDLIPP, CHARLES W., Supt. and Secy., The Rogers Paper Mfg. Co., Inc., So. Manchester, Conn.

DAVIS, RICHARD G., JR., Apprentice, Brown & Sharpe Mfg. Co., Providence, R. I.

FERGUSON, JOHN F., Genl. Mech. and Elec. Engr., Williston, N. Dak.

FERGUSON, RICHARD, Mgr., The Grant Lees Gear Co., Cleveland, Ohio.

HARVEY, RICHARD P., Rep., The Blaw Steel Construction Co., Pittsburgh, Pa., and The Concrete Form Co., Inc., Syracuse, N. Y., at San Francisco, Cal.

NORRIS, EARLE B., Assoc. Prof. of Mech. Engrg., The Univ. of Wis., Madison, Wis.

OSBORNE, LOYALL A., Vice-Pres., Westinghouse Elec. & Mfg. Co., New York.

PATTERSON, HENRY R., Supt. Trenton Wks., American Steel & Wire Co., Trenton, N. J.

POOLE, ERNEST J., Supt., The Carpenter Steel Co., Reading, Pa.

ROGERS, ULYSSES G., Ch. Engr. and Master Mech., M. S. Ortendorf & Co., Chicago, Ill.

SMETTERS, SAMUEL T., Asst. Bridge Engr., The Sanitary Dist., Chicago, Ill.

VON SCHLEGELL, FREDERICK, Dist. Mgr., Allis-Chalmers Mfg. Co., Chicago, Ill.

WALTHER, PAUL H., Vice-Pres., H. R. Heinicke, Inc., New York.

WHITNEY, HERBERT A., Cons. Engrg. Work, Whitney Engrg. Co., Tacoma, Wash.

FOR CONSIDERATION AS ASSOCIATE-MEMBER OR JUNIOR

BOWN, CARLOS W., Genl. Foreman of Mch. Shop, Chile Exploration Co., Chuquicamata, Chile.

COVE, JAMES R., Master Mech., Mass. Cotton Mills, Lowell, Mass.

EBELING, FREDERIC O., Engr. and Draftsman, Robins Conveying Belt Co., New York.

FISK, GUSTAF L., Designer, Cambria Steel Co., Johnstown, Pa.

JACKSON, JOHN R., Asst. Engr. of Tests, A. T. & S. F. Railway Co., Chicago, Ill.

FOR CONSIDERATION AS JUNIOR

HUBBELL, RICHARD L., Inspector, with D. C. & W. B. Jackson, Newark, N. J.

JACKSON, EARL E., Mech. and Cons. Engr., New York.

JOHNSON, ADOLPH T., Student, Denver, Colo.

KITE, HENRY J., Asst. Maintenance Engr., Chester Plant, American Steel Foundries, Chester, Pa.

MCBRIDE, FRANCIS R., Grad. Student of Cornell Univ., Portland, Ore.

MACEWAN, THOMAS S., with American Radiator Co., New York.

VAN VALKENBURGH, MERRITT, Draftsman, Pwr. Installation Dept., De La Vergne Mch. Co., New York.

WALTERS, WILLIAM T., Inspector, Mech. Dept., Illinois Central R.R., Memphis, Tenn.

WEBER, SAMUEL, JR., Home Off. Engr., Globe Indemnity Co., New York.

APPLICATIONS FOR CHANGE OF GRADING

PROMOTION FROM JUNIOR

BOND, FRANCIS M., Mech. Engr., Remington Typewriter Co., Ilion, N. Y.

BROOKS, LOUIS C., Elec. Engr., General Elec. Co., Schenectady, N. Y.

ROBBINS, JOHN L., Mech. Engr., Robbins, Gamwell & Co., Pittsfield, Mass.

SUMMARY

New Applications	32
Applications for change of grading:	
Promotion from Junior	3
	35

APPLICATIONS TO BE IN TIME FOR THE ANNUAL MEETING MUST BE ON FILE BY AUGUST 23

The fact that it takes at least three months to complete an election to membership, makes it necessary to post, in the September issue of The Journal, applications for membership which are to be acted upon in season for successful candidates to attend the Annual Meeting as members of the Society.

Members who have friends wishing to join the Society this year will be interested in having this information available, as many do not realize that it is necessary to take action so far in advance.

This is the most desirable time of the year at which to apply, because newly-elected members not only have the privilege of participating in the Annual Meeting, but obtain membership in time to have their names included in the Year Book of the Society, which goes to press annually on January 2d; they also have the opportunity of taking part in any of the meetings held by Local Sections in fourteen of the principal industrial centers of the country.

The advantages offered members are being constantly increased with an aim to fill completely the broad field of usefulness of a national engineering society, efficiently advance the interests of the profession as a whole and be especially helpful to every member of the organization.

Information regarding the Society and the requirements for membership will be promptly forwarded to any persons suggested by members.

SPRING MEETING PAPERS

At the Spring Meeting held at Buffalo, June 22-25, fourteen papers were presented, comprehensive abstracts of which are to be published in The Journal with an account of the discussion. Pamphlet copies of the complete papers without the discussion are available at the prices named in each case. Later, the papers which appear in volume 37 of Transactions may be had in pamphlet form with the discussion added.

A STUDY OF AN AXLE SHAFT FOR A MOTOR TRUCK

BY JOHN YOUNGER, BUFFALO, N. Y.

Member of the Society

While the investigation herein described is one which the writer made to determine the cause of failure of an axle shaft for a large motor truck and also the remedy adopted, it has a very much wider application than to motor trucks, and is testimony to the value of heat-treated steels.

The shaft is shown in Fig. 7 and with its adjacent parts in Fig. 1. The flutes or splines at the ends are slightly free so that the shaft is under no constraint except to move in a rotary path; in other words it is intended to be subject to pure torsional stresses, with no complicating bending effects. The shaft was made from $2\frac{1}{4}$-in. diameter chrome nickel bar, turned all over to 2.1235 in. diameter. The shafts broke in service as shown by the illustrations, Figs. 2, 3, 4, and 5. The specifications of the steel read as follows:

CHEMICAL

	Per cent.
Carbon about	.20
Chromium about	1.5
Manganese about	.30
Nickel about	4.00
Silicon about	.20
Phosphorus and sulphur below	.04

PHYSICAL

	Lb. per sq. in.
Elastic limit	90,000
Maximum strength	105,000
	Per cent.
Reduction in area	66
Elongation	25

The following are the particulars of the motor truck upon which all calculations of strength must be based:

Motor develops 44 h.p. at 1000 r.p.m. under average conditions.

Transmission reduction is 3.77 to 1.

Worm gear reduction is 9.75 to 1.

Total reduction, 36.8 to 1.

From various tests the efficiency of the transmitting mechanism between motor and axle shafts on this gear ratio is about 75 per cent., so that therefore 33 h.p. are transmitted as a maximum by the shafts at 27 r.p.m. But, in common with usual road vehicle practice, a differential gear is fitted, so that the power transmitted by each shaft at the wheel is only half the total; the shaft shown in Fig. 7, therefore, is under maximum pure torsional stress due to the transmission of $16\frac{1}{2}$ h.p. at 27 r.p.m.

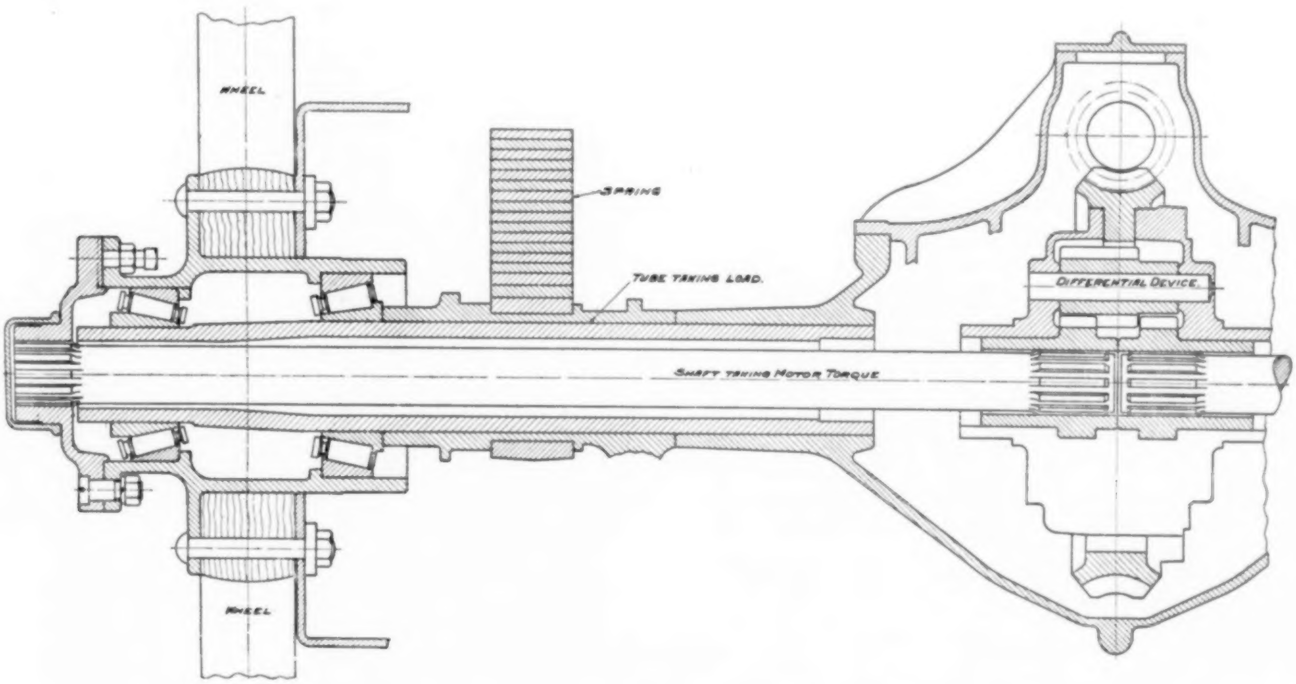


FIG. 1 DIAGRAMMATIC DESIGN OF TRUCK REAR AXLE SHOWING LOCATION OF SHAFT

[1] Presented at the Spring Meeting of the Society, June 1915. Complete paper may be obtained without discussion; 5 cents to members; 10 cents to non-members.

FIG. 2 CHARACTERISTIC FRACTURE, SHAFT TURNED DOWN

In considering the effective diameter on which to base calculations of stress, the large diameter of $2\frac{1}{8}$ in. would not be accurate, inasmuch as the flutes at the ends weaken the shaft to a considerable extent, as is obvious from Figs. 2 to 5, where the lines of cleavage are clearly seen to start from the corner of the spline. While it is true that a sharp corner is a very dangerous source of weakness, it was impossible to get a radius of more than 0.02 in. at the fillet without reducing the area of bearing surface. Key seats or splines are always weakening elements, but it is unfortunately impossible to do without them. The diameters of the plain shafts were the same as the diameters of the splined shafts at the bottom of the key-ways. The limit of elasticity and the torque at fracture for the splined pieces are seen to be slightly greater than that for the plain. Yet, when we turn to the work required to produce fracture, we find it takes more energy to break the plain shaft than it does the splined. It would certainly seem as if the projections should give an added strength to the shaft; yet in the ultimate their presence seems to hasten its down-fall. This is borne out by the appearance of the fractures in Figs. 3, 4, and 5, and it would seem that, while the splines add a slight extra strength to the shaft under static conditions, they subtract from it under dynamic conditions where fatigue is likely to result.

Taking the energy required to fracture, a plain shaft could be considered 30 per cent. to 60 per cent. stronger than a shaft with splines added. The immediate conclusion therefore would be that calculation for strength should be based at most on the diameter at the bottom of the splines.

In order to try out practically the value of this conclusion, a truck was loaded up to full 5 tons capacity. Its rear wheels were then anchored somewhat in a cradle, which would allow about 6 ft. of travel, Fig. 10. A driver then made the truck surge to and fro, the extent of the alternations being measured. The idea was to give the maximum stress on the axles by obtaining the full force of the motor as well as the rotational energy of the flywheel acting against the inertia of the truck. One shaft was left parallel in its length, the other was turned down in the centre. The former broke first and the latter some little time after, 5141 blows being necessary. The total twist in the second exceeded 700 deg., whereas the twist in the first was through an exceedingly short length, all being concentrated near the end of the splines (Fig. 5). It is interesting to note in Fig. 6 the beginning of the planes of cleavage.

From this test the conclusion is justified that the diameter at the bottom of the splines is to be taken in calculations for strength. Accordingly, the design was changed to that of Fig. 8 in which the diameter at the bottom of the splines is 1.75 in. The shaft formula therefore gives

$$\text{Maximum stress per square inch} = \frac{321{,}000\ \text{h.p.}}{nd^3}$$

$$= 36{,}500\ \text{lb. per sq. in., approx.}$$

This gives a factor of safety of 2.5 based on the elastic limit, or 2.9 based on maximum tensile strength.

FIG. 3 CHARACTERISTIC FRACTURE, PARALLEL SHAFT

Regarding braking problems, this particular design of truck has a powerful brake located near the transmission, so that all the braking effort is transmitted by the rear axle shaft to the wheels. We are quite safe in assuming a maximum load on each rear wheel of 8000 lb. and a coefficient of adhesion of the rubber tire to the road, of 0.6. The diameter of the wheels is 40 in., so that torque on shaft is 96,000 in.-lb. The writer does not believe that we really get this

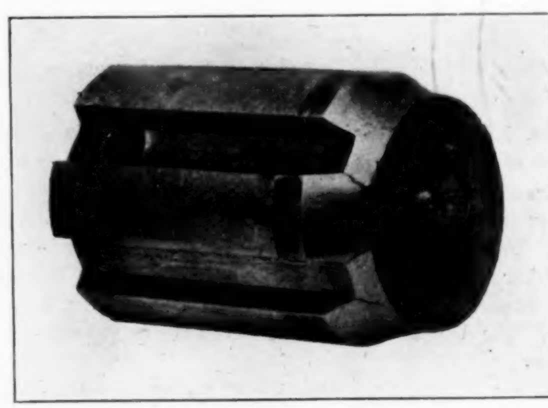


FIG. 4 EFFECT OF SPLINE

torque owing to the elastic rubber tires absorbing part of this blow; but assuming that it were obtained, we would have a maximum stress of 93,000 lb. per sq. in. set up in the axle from the formula

$$\text{Twisting moment or torque} = \frac{\pi f r^3}{2}$$

(It must be understood that the above loads are not normal working loads, but are the maximum that can be expected. It is obvious, therefore, that the shafts which have broken may have been considerably overstressed, although a large number of these actually ran high mileages up to 30,000 and 40,000 miles before breaking. For this reason, it was felt that a comparatively small increase in strength might be sufficient to prevent such breakages and a set of experiments was put in hand to determine the governing factors. The necessity for this lay in the fact that it was almost impossible to increase the diameter of the shafts, which was, of course, the obvious step to take.

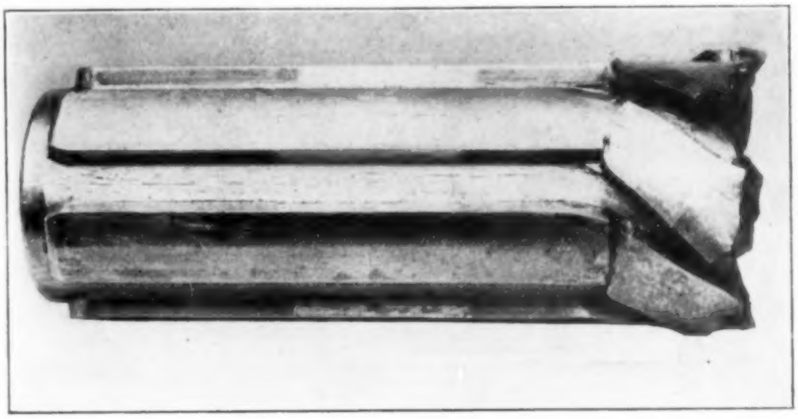


FIG. 5 CHARACTERISTIC FRACTURE

A study of the fractures shown in Figs. 2 to 5 convinced us that the large splines were a very grave source of weakness. If each spline is considered as a small cantilever of breadth $2b$ jutting out from the shaft, with a load of $2W$ upon it, the bending moment at the junction will be $2Wb$; if we take double the number of splines, but keep the same total bearing area, each spline will have half its former breadth and carry half its former load and the bending moment will then be $\frac{Wb}{2}$, or only $\frac{1}{4}$ of the above. In addition to the gain in strength by this change, the diameter of the shaft at the bottom of the splines can be increased by the height of one spline, and yet keep the outside diameter the same. It was felt, also, that, as the strength should be calculated from the diameter at the bottom of the splines, it would be advisable to turn down the shaft in the middle and so reap the advantage of having it uniformly strong throughout its length, and avoid trouble due to sudden changes in torque-resisting values. This, therefore, gave a shaft (Fig. 9) with 12 splines and with effective diameter increased from 1.75 in. to 1.8965 in., representing an increase in strength of

$$\frac{1.9^3}{1.75^3} = \frac{6.86}{5.36} = 28 \text{ per cent approx.}$$

The body of the shaft was ground and polished to avoid all scratches. It was found from examination of fractures that the slightest flaw was enough to start a breakdown. Particular attention was given to the junction of the main body of the shaft with the parts of larger diameter used for the splines, to avoid grooving of the filleting tool.

The designer naturally looks first to the manufacturing end as the cause of his troubles and one of the first investigations was to assure that the axle was subjected to pure torque and not a combined bending and twisting stress. Half a dozen complete axles, some of which had run up large mileage with no fracture, and the remainder had fractured in their early life, were inspected in detail; no difference was found, the only errors present being those that fell within what could only be considered as limits of tolerance. This disposed effectually of improvement being effected in machining process.

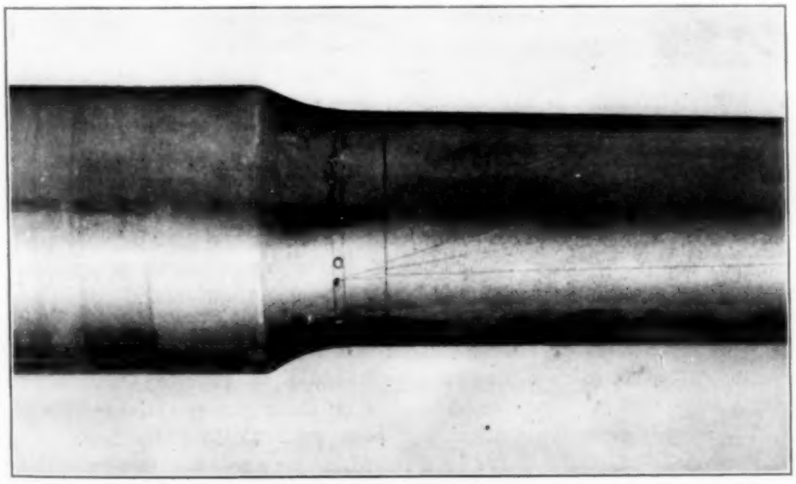


FIG. 6 LINES SHOWING PLANES OF CLEAVAGE IN A SHAFT ABOUT TO BREAK

The other variables being disposed of, the question of material only remained. It had first been the impression that the best material available was being used, and certainly the first physical tests indicated a high grade of alloy steel. The writer had noticed the curious fact, however, that the energy required to fracture a piece of ordinary soft mild steel was practically the same as that required to fracture an exactly similar piece of high-grade alloy steel. Several tests which the writer has witnessed have even shown that a soft steel bar requires more energy to break it than does a hardened bar. The question, therefore, at once suggested itself: "Should the shaft be of a softer steel capable of twisting more under a suddenly applied load, and afterwards returning to normal conditions; or should it be of a very much harder steel, which would be more rigid and not deflect so much, but which would require a greater load to break?" The writer reasoned that if the elastic limit could be raised materially, the shafts would stand up better. Experiments made with small heat-treated specimens, which

could be bent by hand, indicated that this was on the right path and accordingly, after some experiments, two shafts were heat-treated to 175,000 lb. elastic limit (measured in the usual way), and tested on a truck in very severe service; these stood up.

Further tests showed the desirability of increasing the carbon content somewhat, and several shafts were made to the new specifications and sent out on hard service with excellent results. The material was a domestic steel of the following characteristics:

CHEMICAL	Per cent	PHYSICAL	Lb. per sq. in.
Carbon about	.30	Elastic limit	175,000
Manganese	.50	Tensile strength	185,000
Chromium	1.5		Per cent
Nickel	3.5	Elongation per cent in 2 in.	14
		Reduction of area	53

These experiments proved so satisfactory that in September, 1913, a number of these heat-treated shafts were sent out to replace others. Not one of these nor the original experimental shafts have broken, to the best of the writer's knowledge.

The shafts are machined from hot-rolled bars already heat-treated to show an elastic limit of about 100,000 lb. They are then heated in a gas furnace to a temperature of between 1450 and 1500 deg. fahr., and quenched in oil. (This double treatment is to insure the grain being properly refined.) They are then reheated to a little over 700 deg. fahr., and allowed to cool slowly in the air.

Some trouble was experienced at first with warping, but slight experimenting showed they could be readily straightened when hot, under a press. Each individual shaft is then put under the brinell hardness machine, and its brinell number read at the ends and the middle of the bar. This should be 402 to 444. It is then wrapped around with a metal tag, used with the idea of getting reliable results on the different steels we were trying out in our search for a suitable material. In this connection it is interesting to note that 5 per cent nickel steels, chrome vanadium steels, and air hardening steels were tried out and so far all have been standing up to service. The physical specifications of all these steels are very much alike. The success, therefore, seems due entirely to the higher elastic limit, especially as a number of these axles had six flutes and were not of the later 12-flute type.

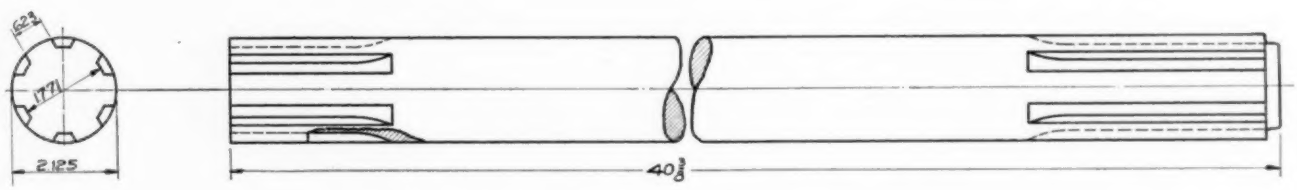


FIG. 7 THE ORIGINAL SHAFT

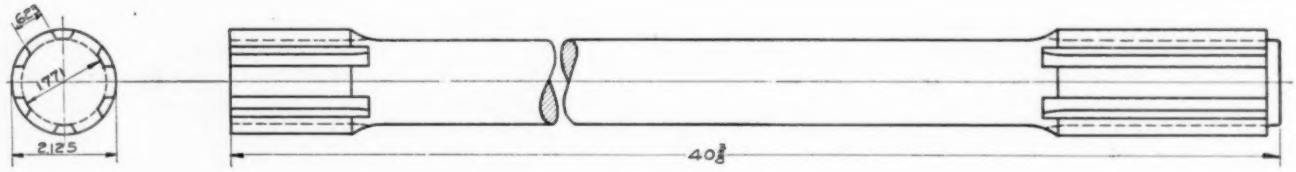


FIG. 8 SECOND DESIGN OF SHAFT

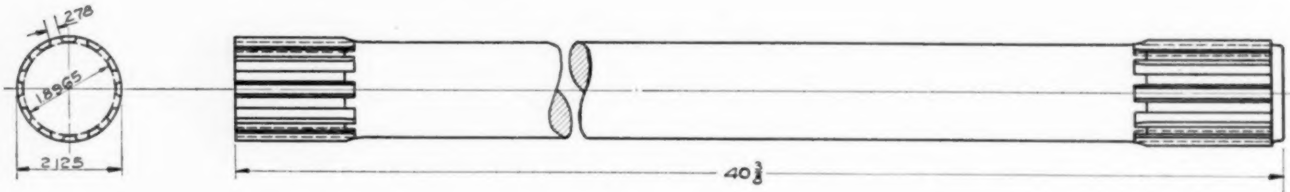


FIG. 9 FINAL FORM OF SHAFT

As a secondary result of the investigations it was thus definitely established that under pure torsional conditions the strength of a shaft is increased by increasing its elastic limit by heat treatment. It would naturally follow, therefore, that similar results could be expected from other components under tensile or shear stress, and accordingly greater attention has been paid to heat treating. The elastic limit has been raised in many pieces with corresponding advantage and, in addition, as a special measure of precaution, each important structural forging or bar is submitted to test on either the scleroscope or the brinell machine to insure that the piece has been properly treated. Both these machines give very reliable readings which can be directly compared with the elastic limit, and by their use a number of forgings seemingly all right, but actually either too hard or too soft, have been detected.

As regards the economic aspect of the use of heat-treated steels, it is found that this process costs between 2 and 2½

cents per lb. and as the strength can in many cases be nearly doubled it clearly effects a large saving. Alloy steels, properly heat treated, are indispensable for motor truck work, as their capacity to resist fatigue is very great. The writer looks forward to their extended use among other mechanical engineers, just as the ball bearing first introduced for cycle and automobile work is now becoming a universal friction saver. As a permanent repair the heat-treated piece of steel is in many cases worth its weight in gold.

DISCUSSION

H. WADE HIBBARD said that, as a member of the Jury of Awards in San Francisco in the Bureau of Engineering, he made use of his privilege to inquire from many of the exhibitors regarding the use in power machinery of heat-treated alloy steels, and confessed that it was a disappointment to find how little it was being used.

He would ask the author to tell in his closure what he means by "elastic limit?" Is it the commercial elastic limit or drop of the beam; or is it a more scientific elastic limit obtained by means of an extensometer, electric contact or otherwise?

With reference to the strains which occur in connection with the reversal of loads, there are Wöhler's experiments and the experiments of those who have followed Wöhler, accounts of which are to be found in any good book on machine design.

CORNELIUS T. MYERS[1] (written). Mr. Younger has treated his subject with characteristic thoroughness and the conclusions set forth, I believe, are worthy of more than mental note by those members of the Society to whom the matter is at all pertinent. The strides made by the automobile industry, comparatively a youngster among the industries of the nation, have not been accomplished without much careful application of mechanical and metallurgical engineering. Analogous problems confront us in the older branches of industry and the suggestions that can be gotten from even a cursory study of the methods in vogue in automobiledom should be well worth while.

RADCLIFFE FURNESS[2] (written). I should like to point out that by increasing the carbon in the material the author increased the true elastic limit and, therefore, the proportion between this and the yield point, thus having a much greater factor of safety in the higher carbon material than existed in the low carbon material.

The two points which are brought forcibly to my mind by Mr. Younger's paper are: First, the desirability of an engineer making a thorough and careful study of the physical properties of the metal which he has in mind to use, in conjunction with the work that he expects this metal to perform, the test conditions being exactly similar to the actual conditions. This has been done by the author in his paper, to my mind, in a most thorough manner.

Secondly, Mr. Younger mentions that alloy steels properly heat-treated are indispensable to motor truck work. Since this is so, it immediately comes to the mind of anyone familiar with metallurgy that the converse is true: namely, that alloy steels improperly heat-treated are actually a menace to all work where they are used and, in addition, should never be used when not given a known and thoroughly tried heat treatment.

In the fabrication of any steel forging, one is obliged to heat the steel above the critical temperature, which is the temperature at which remarkable changes take place in the molecular arrangement. Since the final physical properties depend upon the rate at which the steel cools through the critical range, the number of degrees heated above the critical range, or the time that it has been held at the temperature

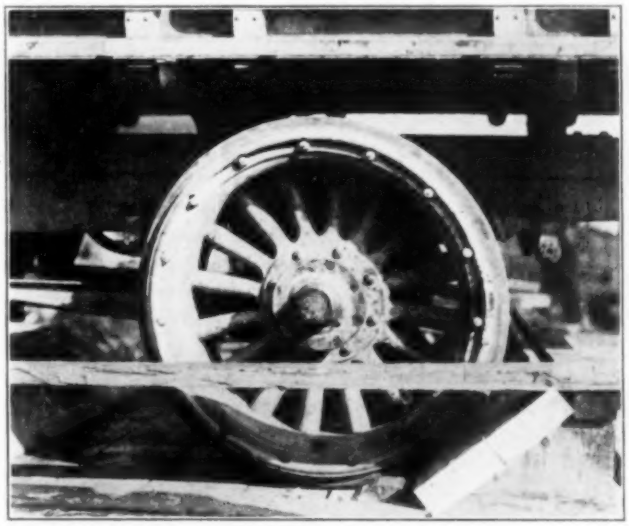


FIG. 10 "CRADLE" IN WHICH TRUCK WAS SURGED TO AND FRO BY ITS OWN POWER

above the critical range when forgings are being manufactured, one can readily see that forgings are subjected to heat treatment in the process of fabrication.

Alloys are added to steel because they emphasize the changes that can be brought about by heat treatment in the molecular arrangement and thus increase the physical properties that can be obtained from the material in hand. Thus, by the addition of alloys, one is emphasizing the difference that can be obtained by varying heat treatments. If the forgings are given no definite heat treatment and are being turned out at different rates, they will be subjected to varying heat treatments and, although it is possible in fabrication to turn out an article which has all the properties of a piece that has been put through a carefully thought-out and prescribed heat treatment, the likelihood of accomplishing this, when the chances of producing other results are infinite, is so small as to be negligible. In addition, one would have many forgings of varying physical properties from the varying heat treatments which they of necessity receive. It becomes necessary, therefore, to treat the material to bring it to a known standard; and, since one has increased the susceptibility by addition of alloys, it is evidently more necessary to heat-treat alloy steels than in the case of simple carbon steels.

It is the duty of all who are interested in the success of alloy steels to emphasize on all occasions the desirability of putting the steels into the condition which will give the best possible results, and of removing the common but fast dying

[1] Engineer, The Timken-David Brown Co., Detroit, Mich.

[2] Midvale Steel Co., Philadelphia, Pa.

impression that a steel, because it is a nickel, nickel-chrome or chrome-vanadium steel, is better than a plain carbon steel, no matter what heat treatment it may have received, when as a matter of fact the contrary is really true.

The Author: In reply to Mr. Furness as to the probability of a mistake in heat-treated alloy steels, one method of guarding against this is to subject each individual forging to either a brinell test or a scleroscopic test.

Forgings of alloy steel are expensive and the author believes that it is just as necessary to inspect them for the heat treatment as it is to put the gage or a rule alongside of them to find out if they measure correctly. For that reason, therefore, he has an inspection put on each forging consisting of either a scleroscope test or a brinell test in order to insure that the heat treatment has been properly carried out. It is found these two tests give a very good indication of the state of the metal.

With regard to Professor Hibbard's question, the elastic limit of 175,000 lb. is by drop of beam,—the ordinary commercial elastic limit. The extensometer tests show a slightly lower elastic limit. From observation of tests of the axles and from breaking pieces of steel, the author feels that the real elastic limit is lower than that obtained by the drop of the beam. For this reason, many of the axles broke under conditions where they ran perhaps 8,000 to 15,000 miles. It is known that the first calculations were very nearly right, taking into account what might be called a normal elastic limit.

The author once made a test on a truck, driving down town with a pendulum bob in front of him, which was really a rough accelerometer. As the truck accelerated forward, the pendulum bob of course swung backwards and everything seemed to act quite normally until a policeman raised his hand and stopped the machine and then gave a signal to go across the street. The truck then accelerated forward, when suddenly a small machine ran out in front; the brakes were jammed on and the pendulum bob swung right across from backwards to forwards. Several tests were tried after that and the conclusion was reached that the stress on material subject to alternating stresses is not the stress based on what might be called the normal line, but is the summation of the two stresses, and the elastic limit based on this summation should be very much lower, how much lower he did not know exactly. Roughly speaking, the elastic limit is anything from about one-half to two-thirds of what it is thought to be.

Tests made on testing machines appear to be of exceedingly little value. This is perhaps rather a hard thing to say, but it it true, and it is no use making tests on a few specimens of meagre size when the material breaks down when it comes to the practical use of large quantities of full size. The author has come to the conclusion that the practical test is the only real test. All the theoretical tests, the Sankey bending machine tests, the Avery impact tests and the ordinary tensile tests show this high tensile steel actually was not as satisfactory as what engineers call tough material, that is, material of a lower elastic limit, with a higher elongation and higher contraction.

We are still trying to find laboratory machines which will tell us what stresses we actually get in trucks, but we haven't got them yet.

A COMPARISON OF THE PROPERTIES OF A NICKEL, CARBON AND MANGANESE STEEL BEFORE AND AFTER HEAT TREATMENT

BY ROBERT R. ABBOTT, CLEVELAND, O.

Non-Member[1]

THE effect of small quantities of manganese upon the physical properties of annealed steel is fairly well known. Up to about 2 per cent, each 0.01 per cent of manganese increases the tensile strength by about 160 lb. per sq. in. Its effect upon the reduction in area and elongation is very small, slightly increasing the former and lowering the latter. From about $2\frac{1}{2}$ to 7 per cent manganese makes steel extremely brittle, and above 7 per cent this effect disappears and we again have a useful alloy. An 11-per cent alloy has a wide range of use in the cast form for crossing frogs, rolls, gears, etc.; it is usually finished by grinding, as it is nearly impossible to machine.

We can classify the average commercial steels made in this country with carbon less than 0.50 per cent into those with manganese contents approximately (*a*) 0.40 to 0.50 per cent; this group includes the ordinary carbon steel and chrome-nickel steel, (*b*) 0.60 to 0.70 per cent; this group includes nickel and chrome-vanadium steels. This classification represents fairly well commercial practice; English steels fall readily into it, but with German steels the grouping is not so well defined. It is rare to find a steel in this country with manganese above 1 per cent (and below 2 per cent). Abroad, a considerable amount of steel is used, particularly for frames of automobiles, with manganese varying from 1.25 to 1.75 per cent.

Very little has been published regarding the heat treatment of these high manganese steels, and I am therefore presenting a comparison of the effect produced upon the physical properties of three steels of about the same carbon contents. One of these is a plain carbon steel, another a nickel steel, and the third a manganese steel, containing 1.61 per cent manganese. Their analysis is as follows:

	Carbon steel	Nickel steel	Manganese steel
Carbon	C.342	0.336	0.341
Phosphorus	0.014	0.019	0.047
Sulphur	0.029	0.019	0.025
Manganese	0.54	0.55	1.61
Silicon	0.030.	0.188	0.009
Nickel	6.0	3.17	0.0
Chromium	0.0	0.0	0.0
Vanadium	0.0	0.0	0.0
Copper	0.0	0.05	0.02

In these three steels the upper critical temperatures were first determined. Test bars $\frac{3}{4}$ in. in diameter and $4\frac{1}{2}$ in. long were next machined from each steel; one of each kind was annealed by heating in lead to a temperature 5 deg. fahr. above the upper critical temperature, holding there

[1] Metallurgical Engineer, The Peerless Motor Car Co.

Presented at the Spring Meeting of the Society, June 1915. Complete paper may be obtained without discussion; price 5 cents to members; 10 cents to non-members.

about ten minutes, and allowing to cool slowly until the lead solidified. The time of this cooling was about ten hours. The lead was then heated slowly to a temperature of 800 deg. fahr. and the test bars removed. They were then threaded and machined to a standard 2 in. test specimen and ground to a diameter of 0.505 in. (1/5 sq. in.). One end was left longer than the other to allow for hardness tests. They were then pulled in a tensile machine with the following results:

Steel	Elastic	Maximum	Reduction	Elongation	Brinell hardness
Carbon	36,600	67,250	51.0	32.0	120
Nickel	55,000	81,850	59.0	31.2	153
Manganese	61,150	87,850	58.5	29.9	150

From these figures we see that the manganese steel is slightly stronger than the nickel steel, and has practically the same amount of "toughness" as shown by the reduction in area.

For the heat-treated specimens a test bar of the same size was used. The heating was all done in lead and was

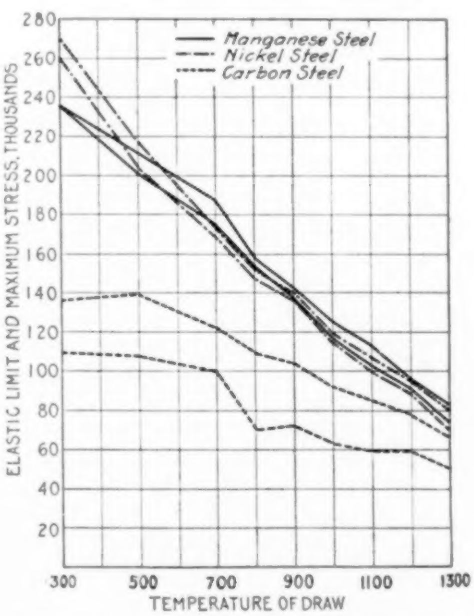


Fig. 1 Tests on Effect of Heat Treatment on Maximum Stress [Upper Curves] and Elastic Limit [Lower Curves]

controlled by a Leeds & Northrup resistance pyrometer. The desired temperature was reached slowly and maintained as nearly constant as possible for ten minutes. All tests which were to be made at the same temperature were made simultaneously. The furnace contained half a ton of lead, and therefore the temperature could be kept very uniform. The bars were quenched in water and were drawn to the desired temperature in a lead furnace holding about three tons, all bars to be drawn at the same temperature being drawn simultaneously. The desired temperature was maintained constant for thirty minutes.

After treatment the bars were machined, ground to a diameter of 0.505 in., and pulled in a tensile machine having an autographic recording device. Hardness tests were made on the long end of the test bar after sawing off and grinding to a flat surface. The following determinations were made: elastic limit; maximum strength; reduction in area; elongation; brinell hardness; scleroscope hardness; rupture stress; energy in foot pounds necessary to cause fracture. The last three determinations are not considered here. Test bars were treated from above the upper critical temperature and were then drawn to the following temperatures: 300, 500, 700, 800, 900, 1000, 1200, 1300 deg. fahr.

In Figs. 1, 2 and 3 are plotted the results of these tests

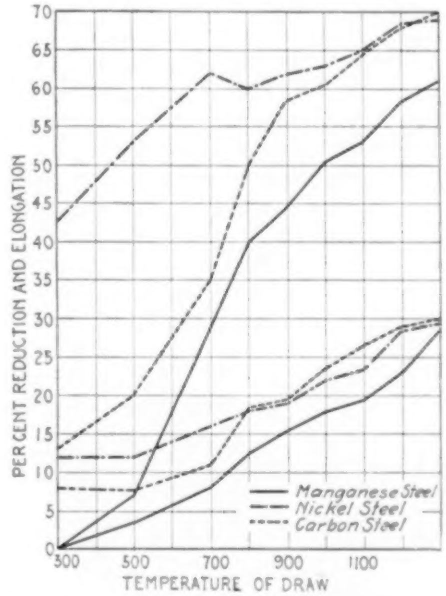


Fig. 2 Tests on Effect of Heat Treatment on Reduction in Area [Upper Curves] and Elongation [Lower Curves]

for the three steels. From these charts it can be concluded that practically the same results can be obtained, as far as strength is concerned, by the heat treatment of a 1.6 per cent manganese steel as for a nickel steel of practically twice the per cent of nickel. However, since the nickel steel also contains 0.55 per cent manganese, we actually have an excess of only 1.06 per cent manganese, which apparently has the same effect as about three times the same amount of nickel.

Now, regarding the "toughness," which for the sake of comparison can be considered as being measured by the reduction in area, we see that the manganese steel does not compare so favorably with the carbon or nickel steel for the same temperature of draw. Evidently also, while manganese increases the reduction in area in annealed steels, it has the opposite effect in heat-treated steels.

The next determination was upon the effect of over- and under-heating during the quenching process. For this purpose ten bars of each steel were quenched as follows: One 5 deg. above the upper critical point, six others at 25, 50, 75, 100, 125 and 150 deg. above and three at 25, 50 and 75 deg. below the critical point. These were all drawn to a temperature of 800 deg. fahr. and the regular tests conducted upon them. The results of these tests are plotted in Figs. 4 and 5. They show that there is very little difference between the nickel and manganese steels as far as over and under heating is concerned.

Summarizing, for a heat-treated $1\frac{1}{2}$ per cent manganese steel the manganese in excess of that contained in a nickel

steel of a corresponding carbon contents (about 0.34 per cent) exerts a strengthening effect equivalent to about three times the same amount of nickel. While the manganese

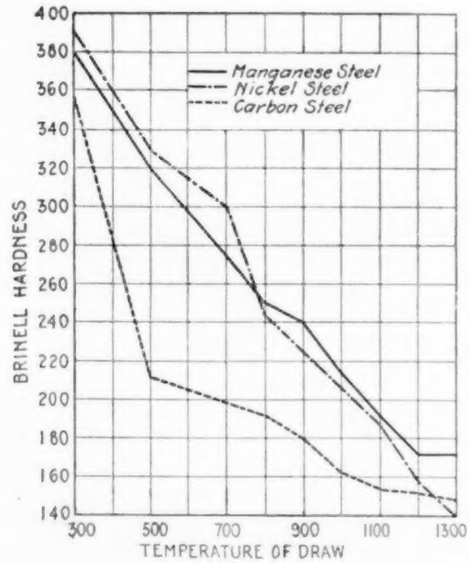


FIG. 3 TESTS ON EFFECT OF HEAT TREATMENT ON BRINELL HARDNESS

effect upon a steel which has not been heat-treated is to increase the toughness slightly, its effect upon a heat-treated steel is decidedly the reverse; in the case of nickel, the effect upon an untreated steel is practically zero, while in a heat treated steel nickel increases the toughness decidedly. An untreated steel containing about 1½ per cent manganese is fully as tough as and is stronger than a nickel steel of about 3¼ per cent nickel.

The following equations represent fairly well the average

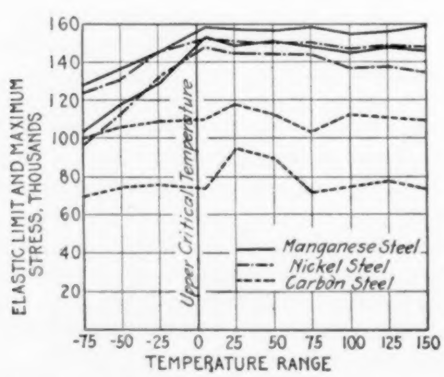


FIG. 4 TESTS ON EFFECT OF OVER- AND UNDER-HEATING ON MAXIMUM STRESS [UPPER CURVES] AND ELASTIC LIMIT [LOWER CURVES]

values of the elastic limits, maximum strengths, reduction in area and elongation of the three steels.

E = elastic limit in pounds per square inch.
M = maximum stress in pounds per square inch.
r = reduction in area in per cent.
e = elongation in per cent.
T = temperature of draw in fahrenheit.

For manganese steel

$$E = 284{,}000 - 163\,T$$
$$M = 288{,}000 - 159\,T$$
$$r = -19 + .068\,T$$
$$e = -10 + .028\,T$$

For nickel steel

$$E = 302{,}000 - 183\,T$$
$$M = 314{,}000 - 188\,T$$
$$r = 40 + .024\,T$$
$$e = 3.5 + .018\,T$$

For carbon steel

$$E = 134{,}000 - 66\,T$$
$$M = 170{,}000 - 77\,T$$
$$r = -5.8 + .063\,T$$
$$e = -3 + .026\,T$$

DISCUSSION

HENRY M. HOWE[1] (written): The manganese steel to which Mr. Abbott calls attention has come into use in this country more widely than might be inferred from his remarks. The late Maunsell White developed a steel of over

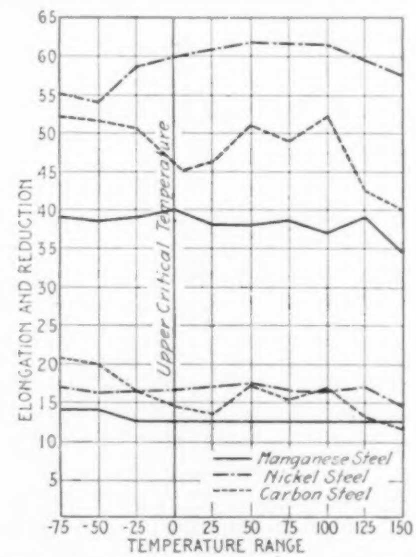


FIG. 5 TESTS ON EFFECT OF OVER- AND UNDER-HEATING ON REDUCTION IN AREA [UPPER CURVES] AND ELONGATION [LOWER CURVES]

1 per cent. manganese and somewhat lower in carbon than Mr. Abbott's, and this has gone into very wice use where high quality is needed.

Roughly speaking, 1 per cent of manganese is about equivalent to 2 per cent of nickel, at least 1 per cent of manganese accomplishes some of the more important things which double the quantity of nickel accomplishes.

The reason why manganese and nickel are useful for such steels is a very simple one. In order to develop the properties of a given steel very highly it should be heated above the transformation range, in order to cause the usual rather coarse masses of ferrite to become reabsorbed. The steel should then be cooled rapidly, lest in slow cooling through the transformation range the ferrite again should form coarse masses.

If this cooling is done by quenching in water or oil the resultant steel is too brittle; that is to say, the chemical trans-

[1] Columbia University, New York.

formation is arrested and at the same time serious internal stresses are set up. In order to permit the transformation to complete itself, so that the chemical brittleness may be removed, and in order to relieve the stresses which are also a cause of brittleness, the steel must next be reheated, as in tempering or moderate annealing. The rise of temperature enables the chemical transformation to complete itself, so that the metal becomes transformed into ferrite and cementite. It also releases the stresses. But this is accompanied by an incidental damage, namely that the resultant ferrite coalesces more and more into larger and larger masses, and with the increase in the size of these masses the quality of the steel falls off progressively.

The advantage of manganese and nickel is that they cause this coalescence and coarsening to occur very slowly. As a consequence, when the steel is reheated so that the transformation occurs, removing the chemical brittleness, and that the stresses are removed, thus removing the second cause of brittleness, the coalescence of the ferrite is very much slower than in steel with less manganese.

And in general this same sluggardizing effect of manganese and nickel under miscellaneous conditions gives rise to a finer structure than would otherwise form. Their effect in this respect is like that of vanadium, only less powerful.

ON MEASURING GAS WEIGHTS

BY THOMAS E. BUTTERFIELD, SOUTH BETHLEHEM, PA.

Member of the Society

The author is interested in accurate methods of determining gas quantities, such as the quantity of gas delivered by a fan, a blower, or a compressor, or the quantity of gas generated by a producer, furnace or other combustion apparatus, or finally the quantity of gas used or consumed for various purposes.

In reporting results on gas measurement, the use of volume as an expression of quantity or mass should be eliminated. Gas quantities should be expressed by weight. Volumes of ordinary standard gases even at standard pressure and temperature are useful in determining quantities, but it is almost always misleading to use such volumes as measures of quantity or mass.

The name of a gas even to the engineer is no exact indication of its constitution or physical properties, because commercial gases made by the same process or indeed in the same apparatus are subject to important variations in the proportions of their principal constituents.

Density of a gas may be readily calculated from the chemical analysis, but the result of such calculation giving quantity in pounds should always be reported by the investigator. For fuel gases this would also imply that thermal quality be expressed in heat units per pound, and in general all volume data should be regarded as of only collateral interest.

It is usual to consider that after generation commercial gases retain their composition unaltered. Even gases containing no condensible tarry constituents, however, suffer considerable changes in their moisture content with changing temperature, due to the corresponding change of vapor tension of steam. If a gas be used at the same temperature with different treatment after water contact or with no water contact, the moisture content will be quite different. The ordinary volumetric analysis gives the composition of the dry gas, which is different from the actual composition as generated or used.

Where accuracy is of importance the moisture content should be measured.

Gasometer measurements furnish the most accurate method of determining gas volumes and weights. It is essential that the temperature of the gas should be uniform in every part of the gasometer.

Displacement gas meters, whether of wet or dry type, are very accurate where the volume of the measuring chamber is unalterable or accurately known at every instant, and where the pressure, temperature and humidity of the gas at the instant of filling are also known, or nearly the same as at calibration. This is not true in fluctuating flow.

The pitot tube, venturi meter, and orifice methods of measurement depend for accuracy on the preservation of a constant relation of velocities over an entire cross-section, accurate measure of this cross-section, and accurate measurement of gas density. It is evidently as easy to calculate weights as volumes from the readings of such meters. They are not at all adapted to measure a rapidly fluctuating flow or a flow accompanied by eddies.

Where the specific heat of the gas is known its weight may be calculated by the change in temperature produced by the addition or abstraction of a known quantity of heat.

Where large volumes of gas are to be measured reliable shunt methods could be developed for measuring part of the flow, just as electric current is measured. A rational form for such a shunt would be a double walled diaphragm placed in the main through which the gas passes. The diaphragm is pierced full of holes all of the same size, say of about one inch diameter. From one in twenty to one in one hundred of these holes communicates with the interior of the diaphragm, the remainder pass through both walls, and are short, slightly flaring tubes with sharp edges. The gas from the interior of the diaphragm is carefully metered and returned to the main, and gives a measure of the total amount flowing. This method should give quite accurate results with either continuous or fluctuating flow.

Finally, we have methods which depend on chemical analysis of the gas and measurement of one constituent which forms a known percentage of the whole.

Various metallurgical formulae are in use for obtaining the result from volumetric analyses of fuel and burnt gas. It is the author's belief that the following method, based on reduction of volumetric analysis to weight analysis is simpler and safer than other methods, and the principal object of this paper is to urge its adoption in a standard code.

An example will illustrate the method. The fuel gas contains 2 per cent moisture. The volumetric analysis of dry fuel gas is $CO = 6$ per cent, $CO_2 = 2$ per cent, $CH_4 = 40$ per cent, $C_2H_4 = 4$ per cent, $H_2 = 46$ per cent, and $N_2 = 2$ per cent. After burning with air containing 1½ per cent moisture the volumetric analysis of the dry products of combustion is

$CO_2 = 8.8$ per cent, $O_2 = 4.5$ per cent, and $N_2 = 86.7$ per cent.

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It is required to find the ratio by weight or volume of the burnt gas to fuel gas. Call this ratio a_w for weight, or a_v for volume. Then, necessarily, the weight of air is $a_w - 1$, if fuel gas weight be taken as unity.

The four elements, carbon, hydrogen, oxygen and nitrogen are the only ones present in the three gases, and the volumetric analyses are reduced to weight analyses giving proportions of these four elements. The actual volumetric analysis of the fuel gas including moisture is

Constituents	CO	CO_2	CH_4	C_2H_4	H_2	N_2	H_2O
Per cent	5.9	2	39.2	3.9	45	2	2

The total carbon weight is

$$12\,(5.9 + 2 + 39.2 + 2 \times 3.9) = 659.$$

The hydrogen weight is

$$1\,(4 \times 39.2 + 4 \times 3.9 + 2 \times 45 + 2 \times 2) = 268.$$

The oxygen weight is

$$16\,(5.9 + 2 \times 2 + 2) = 190.$$

The nitrogen weight is

$$28 \times 2 = 56.$$

The density of the gas is

$$\frac{659 + 268 + 190 + 56}{200} = \frac{1173}{200} = 5.86 \text{ times that of hydrogen.}$$

The weight analysis by elements is: carbon $= \frac{659}{1173}$, hydrogen $= \frac{268}{1173}$, oxygen $= \frac{190}{1173}$ and nitrogen $= \frac{56}{1173}$, or in per cent $C_1 = 56.1$ per cent, $H_1 = 22.9$ per cent, $O_1 = 16.2$ per cent, and $N_1 = 4.8$ per cent, using the subscript "one" to denote fuel.[1]

Similarly the weight analysis of air is: $H_2 = 0.1$ per cent, $O_2 = 24$ per cent, and $N_2 = 75.9$ per cent, with a density $= 14.34$ times that of hydrogen. We use subscript "two" to denote air.

The weight analysis of the "dry" products of combustion is: $C_{30} = 3.6$ per cent, $O_{30} = 14.4$ per cent, $N_{30} = 82$ per cent and the density is 14.8 times that of hydrogen. We use subscript "30" to denote "dry" products of combustion.

The weight of any element in the burnt gas (before condensation of moisture) is the sum of the weights in fuel gas and air, giving rise to the four fundamental equations:

$C_1 + (a_w - 1)\,C_2 = a_w\,C_3$, carbon equation ....[1]

$H_1 + (a_w - 1)\,H_2 = a_w\,H_3$, hydrogen equation.........[2]

$O_1 + (a_w - 1)\,O_2 = a_w\,O_3$, oxygen equation..........[3]

$N_1 + (a_w - 1)\,N_2 = a_w\,N_3$, nitrogen equation...........[4]

Since the weight of carbon in air is negligible

$$C_1 = a_w C_3 \text{ or } a_w = \frac{C_1}{C_3} \quad\ldots\ldots\ldots\ldots\ldots\ldots[5]$$

Since the relative proportions of carbon and nitrogen in the burnt gas cannot be altered by the separation of moisture, we may write

$$\frac{\text{carbon in fuel plus carbon in air}}{\text{nitrogen in fuel plus nitrogen in air}} = \frac{\text{carbon in dry burnt gas}}{\text{nitrogen in dry burnt gas}}$$

or

$$\frac{C_1 + (a_w - 1)\,C_2}{N_1 + (a_w - 1)\,N_2} = \frac{a_w C_3}{a_w N_3} = \frac{a_w C_{30}}{a_w N_{30}}$$

Simplifying

$$\frac{C_1}{N_1 + (a_w - 1)\,N_2} = \frac{C_{30}}{N_{30}}, \text{ and } a_w = 1 + \frac{C_1 N_{30} - N_1 C_{30}}{N_2 C_{30}} \quad\ldots.[6]$$

Equation [6] gives a simple expression for the weight ratio from the analyses by weight of fuel and "dry" burnt gas. The weight of moisture in the burnt gas is nine times the total weight of hydrogen in fuel and air, or

$$9\,\{H_1 + (a_w - 1)\,H_2\}$$

and the weight of "dry" burnt gas per pound of fuel is

$$a_w - 9\,\{H_1 + (a_w - 1)\,H_2\}.$$

Then

$$\frac{C_3}{C_{30}} = \frac{N_3}{N_{30}} = \frac{a_w - 9\{H_1 + (a_w - 1)\,H_2\}}{a_w}$$

and

$$C_1 = a_w C_3 = [a_w - 9\{H_1 + (a_w - 1)\,H_2\}]C_{30} \text{ and } a_w = \frac{C_1 + 9(H_1 - H_2)C_{30}}{(1 - 9\,H_2)C_{30}} \quad\ldots\ldots\ldots\ldots\ldots\ldots.[5a[$$

Similarly for nitrogen

$$N_1 + (a_w - 1)N_2 = [a_w - 9\{H_1 + (a_w - 1)\,H_2\}]N_{30} \text{ and}$$

$$a_w = \frac{N_2 - N_1 - 9(H_1 - H_2)\,N_{30}}{N_2 - N_{30}(1 - 9\,H_2)} \qquad [4a]$$

The oxygen in air and fuel less the oxygen that separates from the burnt gas as moisture is equal to the oxygen in the "dry" burnt gas, or

$$O_1 + (a_w - 1)\,O_2 - 8\{H_1 + (a_w - 1)\,H_2\} = [a_w - 9\{H_1 + (a_w\text{T} - 1)\,H_2\}]O_{30}$$

or

$$a_w = \frac{O_2 - O_1 + (8 - 9\,O_{30})\,(H_1 - H_2)}{O_2 - 8\,H_2 - O_{30}\,(1 - 9\,H)_2} \quad\ldots\ldots\ldots..[3a]$$

Applying equations [3a], [4a], [5a] and [6] to the solution of the problem given we use the recapitulation of analyses by weight.

	Fuel	Air	Dry burnt gas
O....................	16.2	24	14.4
N....................	4.8	75.9	82
H....................	22.9	0.1	....
C....................	56.1	....	3.6
Density..............	5.86	14.34	14.8

Then from [3a]

$$a_w = \frac{O_2 - O_1 + (8 - 9\,O_{30})\,(H_1 - H_2)}{O_2 - 8\,H_2 - O_{30}\,(1 - 9\,H_2)} = \frac{0.24 - 0.162 + (8 - 9 \times 0.144)\,(0.229 - 0.001)}{0.24 - 8 \times 0.001 - 0.144\,(1 - 9 \times 0.001)} = 18.05$$

From [4a]

$$a_w = \frac{N_2 - N_1 - 9\,(H_1 - H_2)\,N_{30}}{N_2 - N_{30}\,(1 - 9\,H_2)} = \frac{0.759 - 0.048 - 9\,(0.229 - 0.001)\,0.82}{0.759 - 0.82\,(1 - 9 \times 0.001)} = 18.13$$

From [5a]

$$a_w = \frac{C_1 + 9(H_1 - H_2)C_{30}}{(1 - 9\,H_2)\,C_{30}} = \frac{0.561 + 9(0.229 - 0.001)0.036}{(1 - 9 \times 0.001)0.036} = 17.79$$

From [6]

$$a_w = \frac{C_1 N_{30} - N_1 C_{30}}{N_2 C_{30}} = 1 + \frac{0.561 \times 0.82 - 0.048 \times 0.036}{0.759 \times 0.036} = 17.79$$

The percentage error $\frac{18.13 - 17.79}{18.13} \times 100 = 1.9$. The error evidently lies in the too rough approximation in de-

[1] In the equations which follow, the numerical subscripts do not indicate numbers of atoms.

termining $C_{30} = 0.036$. The value of the check given by the separate determinations is evident. The author has had this method in use for some years with very satisfactory results.

The author has been requested to give reasons why gas quantities should be expressed in weight rather than by volume. There are two very important reasons.

First. If gas quantity is expressed in pounds we have the simplest possible unit. Erroneous statements of weight will not often be made and are easily checked. On the other hand, if quantities are expressed by volume, we must give volume, temperature and pressure both under observed conditions and reduced to some standard pressure and temperature. There is considerable probability of errors in neglecting or forgetting to reduce volume to standard conditions, or in neglecting to state the conditions assumed standard. Further, weight makes an immensely stronger appeal to the senses than volume. This in itself makes it harder for the writer to make errors and easier for the reader to detect errors and comprehend results.

Second. The value of a definite gas in the various industries is determined by its weight rather than by its volume. For instance, in furnace work, it is necessary to furnish a certain weight of air to consume the fuel. In measuring the output of a compressor, it is important to know the number of pounds of air delivered against the discharge pressure. The capacity of an air pump is determined by the number of pounds of air it can remove from a certain vacuum. The capacity of a gas engine is determined by the number of pounds of air and fuel it can draw into the cylinder. In all of these cases the volume is of subordinate interest. Comparison on the basis of volumes is misleading

In a combustion process involving solids or liquids and gases the custom of giving fuel quantities in pounds and air and gas quantities in cubic feet is not conducive to clear thinking. Imagine an investigator stating that a certain number of cubic feet of coal was charged into a furnace! Of course weight of gas cannot be determined ordinarily without calculation. But the calculation involved is not greater than that required to put volume readings in form permitting definite and precise understanding of results.

In reference to the illustrative example given, the author wishes to state that, in his method of calculating the weights of air and burnt gas from a known fuel weight, simple weight calculations are used and combustion formulæ are not used. This is the distinguishing feature of the method. The number of pounds of any element entering a reaction must be the same as the weight leaving. Equations 1 to 4, contain all the fundamental equations, following which the modifications required are shown when the complete analysis of burnt gas, including moisture, is not known. When weight ratio is known, as air, volume ratio can be easily found by dividing by density ratio.

DISCUSSION

ARTHUR M. GREENE, JR., suggested that if the equations or methods given by the author were to be adopted, it would be better if the nomenclature were changed so that the literal values were more suggestive of the things for which they actually stood. One of the great faults in connection with equations is that literal values are so formed as to suggest something entirely different from the things for which they stand.

THE USE OF CORRUGATED FURNACES FOR VERTICAL FIRE TUBE BOILERS

BY F. W. DEAN, BOSTON, MASS.

Member of the Society

I HAVE been impressed for many years with the value of corrugated furnaces for vertical boilers, but only recently have actually used them. By their use staybolts are

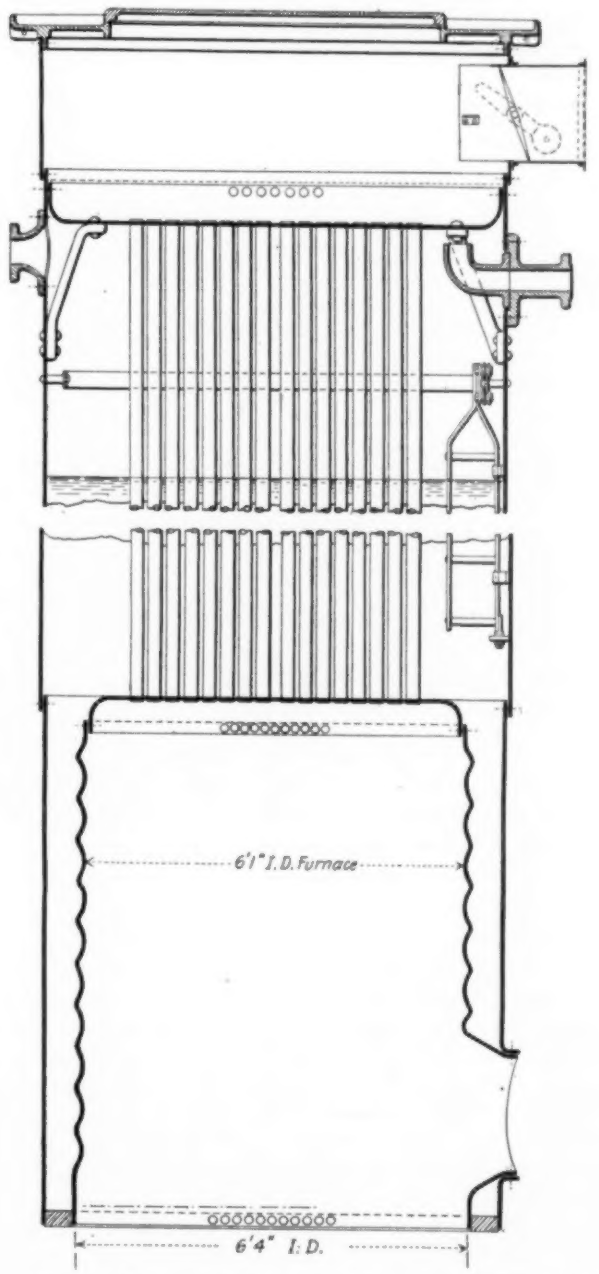

FIG. 1 VERTICAL BOILER WITH CORRUGATED FURNACE

done away with, and as there appear to be no disadvantages in the furnace this is a most important feature. As many hundreds of staybolts are avoided in each boiler, there are

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just so many less opportunities for breakage and needed repairs.

This type provides for expansion and contraction of the tubes in a safe manner, but on account of its somewhat flexible character it should be assumed that it is advisable to support the lower tube plate as near the edge as practicable. The ordinary firebox is rigid vertically and supports the edge of the lower tube plate, but as the corrugated firebox has slight elasticity it is best to hold up as much of the tube plate as practicable by the tubes and provide little or no elasticity in the tube plates. The flat and unstayed portions of the upper and lower tube plates should be made equal in diameter in order to balance.

The behavior of the firebox end of the boiler when under pressure led to some speculation, for the area of the fire door opening theoretically unbalances it. When under hydrostatic pressure, various gauges were used for showing distortion, but none could be discovered.

In regard to sizes of such furnaces the catalogue of the American maker gives 60 in. as the maximum inside diameter, but in fact this company can make them up to 72 in., and almost 1 in. thick. They have been made slightly larger in Germany and the furnace of the boiler illustrated was obtained in that country. If the inside diameter is 72 in., the grate will be 3 in. larger or 75 in. and the grate area 30.68 sq. ft. It is easy enough to generate 200 h.p. on a grate of this size with considerable capacity for forcing beyond this, and there is no difficulty in providing the heating surface for this horsepower.

In regard to pressure, a furnace 72 in. in diameter and 0.95 in. thick will carry 200 lb. If there were sufficient demand for larger furnaces they would probably be forthcoming. The theory of heat transmission through plates, and experience, show that thick furnaces, especially if without riveted joints, are unobjectionable.

The introduction of corrugated furnaces for the fireboxes of the vertical type of boiler is, I think, a real improvement in steam boilers. The type possesses the important qualities of giving maximum and permanent economy, superheating the steam from 20 deg. to 40 deg., being free from brickwork and requiring small floor space per horsepower.

DISCUSSION

W. F. MacGregor (written). In contemplating a change in any well known type of construction, it is natural to consider first the effect on that portion which experience has shown to have given the most trouble. This in vertical firetube boilers is tube leakage at the crown sheet. Our first question is, then, Will a flexible furnace tend to increase or diminish tube leakage, granting that the corrugated furnace is more flexible?

When the first Manning boilers were built, it was thought necessary to provide for the differential expansion between the tubes and shell, and an attempt was made to do so in the O. G. ring, but it was found to be impracticable. The amount of differential expansion cannot be great, and it is questionable if the tubes acting through the medium of the flexible crown sheet can produce a change in length of the corrugated furnace. On the other hand, it is possible to imagine that the corrugated furnace may gradually change in length and tend to produce tube leakage. As to whether the tube leakage will be greater or less with a corrugated furnace can only be shown by experience.

But the principal point in considering any new boiler construction is safety. Before abandoning the stay-bolted construction for other types we should bear in mind its good points as well as the bad ones. The stay-bolted surface is increased in strength by a slight deformation or bulging of the plates, while the corrugated furnace is weakened by any deformation, especially if local in character. Leakage at stay-bolts or a slight bulging of the plates, is sometimes a "blessing in disguise," in giving warning of conditions in the boiler that should be corrected in good time to avoid serious damage or disaster. Broken stay-bolts in stationary boilers are so common as to condemn this type of construction, but when provided with tell-tale holes they do not constitute a source of danger.

After considering safety, durability, efficiency and convenience, we must also take into account the cost of construction, and while the figures showing the cost of the corrugated furnace are not at hand, I believe it is more expensive than the other type. The most apparent advantages of the corrugated furnace in the vertical fire-tube boiler are the decreased resistance to circulation and the increased facilities for cleaning.

H. Wade Hibbard objected to the staying of the top tube sheet of the boiler shown in the figure. He referred to the statements of the author that this particular boiler will carry 300 lb. pressure and that the steam is superheated to as high as 40 deg. superheat. The temperature at the top of the diagonal stay for the tube top-sheet must be very much higher than the temperature of the superheated steam, which means that the top foot of the diagonal stay must certainly be at the temperature of blue heat. It is a well known fact, established by tests and experience, that in the blue heat region iron and steel are brittle; and if bent within the blue heat zone are far more liable to crack than if at a higher temperature or at a lower temperature. As the pressure in the boiler changes, the diagonal stay will be constantly subjected to bending action and there will be danger of the diagonal stay breaking at its bend.

Arthur M. Greene, Jr. If we look sideways at the illustration of this boiler, we have practically a locomotive type boiler, especially if we put the firebox a little eccentric, and I would like to ask the author if he could include in his paper, in the discussion or the closure, some facts as regards the action of the Vanderbilt firebox in locomotive boilers, because the experience of the railroad people with that type of boiler, especially in the firebox end, would be of great value to members of this Society if they should consider the adoption of Mr. Dean's form of boiler.

Forrest E. Cardullo. I agree with Professor Greene with regard to the safety of the general form of design, and also with Professor Hibbard as regards the diagonal stay, but that matter might be very easily taken care of by carrying the boiler, in a conical form, from the joint flush with the crown sheet of the firebox up to the upper tube sheet, so as to eliminate entirely the necessity of staying that part of the boiler.

I see no reason why anyone should build a 200 h.p. vertical tubular boiler. Such a boiler, in my experience, invariably causes stack temperatures of 800 or 1000 deg., which means that it is inherently a wasteful form of apparatus, unless provision is made for utilizing the waste heat.

THE EFFECT OF RELATIVE HUMIDITY ON AN OAK TANNED LEATHER BELT

BY WILLIAM W. BIRD, WORCESTER, MASS.
Member of the Society
AND FRANCIS W. ROYS, WORCESTER, MASS.
Non-Member[1]

It has long been a recognized fact that the weather has a more or less noticeable effect on leather belts. In experimental work it has often been found impossible to duplicate results when testing the same belt on different days. In practice, those who are familiar with the behavior of leather belts have noticed a difference in the action of belts from day to day, under varying conditions of the weather. However, when the generally accepted rules for belting are consulted, it will be found that the discussion of the weather has been entirely omitted for once. Of the several weather conditions which can be noted readily, it was thought that the variation of the relative humidity of the atmosphere would offer the most promising field and therefore the effect of this variation was chosen as the subject for a special investigation.

The most noticeable effect of an increase in the humidity was found to be in the lengthening of the belt. If the distance between the pulley centers remained constant, this lengthening of the belt would decrease the sum of the tensions. On the other hand, the sum of the tensions could be maintained by varying the center distance as the humidity was changed. Thus the field being narrowed to these limited conditions of constant initial length, width, thickness and speed of the belt; diameters of the pulleys; horse power transmitted, and temperature, the investigation was carried out to determine:

a. The effect produced on the center distance by varying the sum of the tensions, the relative humidity remaining constant.

b The effect of the relative humidity on the center distance, the sum of the tensions remaining constant.

c The effect of the relative humidity on the sum of the tensions, the center distance remaining constant.

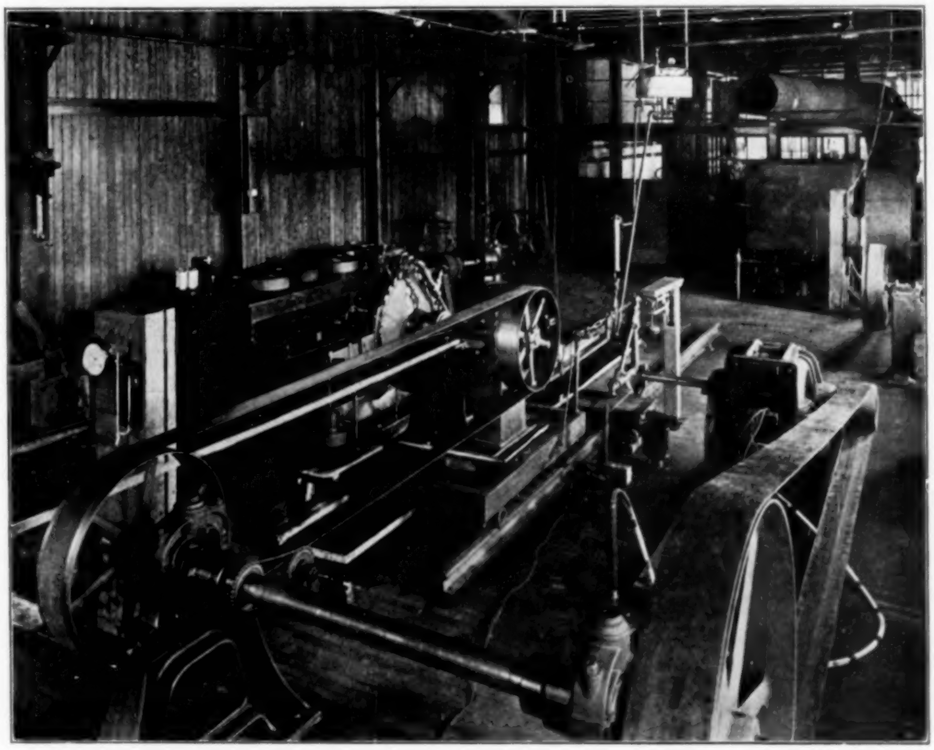


Fig. 1 General Layout of the Apparatus

A general layout of the apparatus used in these experiments, which were conducted at the Worcester Polytechnic Institute, is shown in Fig. 1. It may be described as follows:

A shaft which carries a pulley on one end and an Alden dynamometer on the other is mounted on a carriage which is free to move in a horizontal direction at right angles to the shaft. On the same level with this first shaft and parallel to it, is a jack shaft driven at constant speed. This jack shaft has a pulley on one end the same size as the pulley on the dynamometer shaft and the "belt under test" runs over these two pulleys. The Alden dynamometer furnishes the load, which is equivalent to $T_1 - T_2$ or the difference between the tensions of the tight and slack sides, and the platform scales weighs the sum of the belt tensions or $T_1 + T_2$, as shown in the figure.

In order to measure all of the power transmitted by the belt, the shaft bearings were so designed that they formed a part of the dynamometer. Fig. 2 shows this arrangement in more detail. The bearings consist of pairs of S. K. F. ball bearings in which the shaft turns. The ball bearings are carried in a housing which is free to turn inside of a

[1] Worcester Poly. Inst.

Presented at the Spring Meeting of the Society, June 1915. Complete paper may be obtained without discussion; price 5 cents to members; 10 cents to non-members.

pair of Standard roller bearings. Thus what little friction there may be in the ball bearings will tend to turn the housing which is attached to the dynamometer casing and thereby becomes a part of it.

In the rear of the room, Fig. 1, is a Sturtevant heater and blower, the heater to keep the temperature under control and the blower to circulate the air in the room. A live steam jet inside the heater was used for humidity control. The degree of relative humidity was measured by a precision hygrometer of the hair type, a wet and dry bulb thermometer and a sling psychrometre, a modification of the pattern developed by the U. S. Weather Bureau, the last method giving very satisfactory results.

The belt used in this investigation was a four-inch, single, oak tanned leather belt furnished by the Graton & Knight Mfg. Co. of Worcester. The pulleys were a pair of cast iron crown face pulleys, twenty-four inches in diameter with a six inch face. The initial length of the belt was such that the center distance at 20 per cent humidity, $T_1 + T_2$ equalling 320 lb., was 9 ft. $6\frac{9}{16}$ in.; this makes the belt approximately $25\frac{1}{2}$ ft. long. Standard conditions were assumed to be $T_1 = 240$, or 60 lb. per in. of width, and $T_1/T_2 = 3$, where T_1 = the tension in the tight side of the belt and T_2 the tension in the slack side; this gives $T_1 - T_2 =$ 160 lb. and as the belt speed remained constant at about 1900 ft. per minute, the horse power was approximately 9.21 all of the time. The slip was between 0.8 and 0.9 of one per cent.

Experiments were run to see if a difference in the modulus of elasticity of the belt, when running, could be detected at 20 per cent, 55 per cent and 90 per cent humidity. Tests were also made at these humidities to see if a difference in the slip due to different values of the modulus of elasticity could be shown. No noticeable effect could be detected. The results are plotted as curves in Figs. 3 and 4, and as a surface in Fig. 5.

The three black spots indicated on the surface of Fig. 5 all occur at $T_1 + T_2 = 320$ lb. Now starting at any one of these points and keeping the center distance constant, take the course indicated by the line along which the printing occurs. This line is seen to cross the lines of constant tension, the tension increasing as the relative humidity decreases, or vice versa.

The surface shown in Fig. 5 might well be called the characteristic of this belt, and it indicates in a general way what might be expected from similar belts. Leather itself will vary; the tanning is different; the quantity and quality of belt dressing is never twice the same. All of the factors being more or less unknown, it will be impossible to make definite prediction regarding other belts.

However, in a general way, it may be stated that the effect of a change in relative humidity is greater at high humidities than at low, that the effect is shown more rapidly in a single than in a double belt, and that increasing the humidity shows immediate results while a decrease in humidity takes some little time to be effective.

Curves are given in the paper, derived from Fig. 5 and illustrating, for belts set up at various humidities, the effect of changes in the humidity on the ratio of the tensions. Two of these relations are shown in Fig. 6, for a standard set-up of 55 per cent relative humidity, which is near the normal, and a change in relative humidity will not produce either an excessive ratio of tensions or an undue sum of tensions.

As the higher relative humidities generally occur at temperatures above 70 deg., a series of experiments was run at 50 deg. temperature with the relative humidity varying from 20 per cent to 90 per cent, and another series at 90 deg. temperature, $T_1 + T_2$ and h.p. being constant for all of these tests. These results are shown in Fig. 7, which also has the corresponding results at 70 deg. from previous experiments. This would indicate that the belt lengthens as the temperature increases, the relative humidity remaining constant; that the amount of this lengthening is somewhat greater at high relative humidities than at low relative humidities; and that the lengthening due to an increase in the relative humidity is greater at temperatures higher than 70 deg. and less for temperatures under 70 deg.

It would appear from the experiments that the lengthening

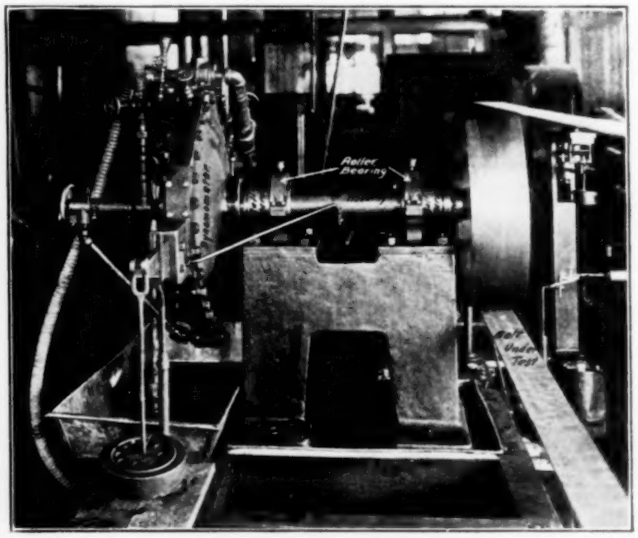


FIG. 2 DETAIL VIEW OF THE DYNAMOMETER

of the belt which takes place when the humidity increases is very nearly proportional to the relative humidity, while no definite relation to absolute humidity exists. The fact that the lines in Fig. 7 are not parallel would indicate that either there is some slight effect due to changes in the absolute humidity or, what is more probable, that the coefficient of expansion is greater at 90 deg. than at 20 deg. temperature.

The general conclusions are:

First. If a belt be set up at low relative humidity, slipping will probably occur if the relative humidity increases to any great extent, especially if accompanied by a rise in temperature.

Second. If a belt be set up at high relative humidity, excessive pressure on the bearings and stretching of the belt will result from a decided decrease in relative humidity, especially if accompanied by a fall in temperature.

Third. If a belt be set up at a medium relative humidity, the tensions will not be excessive at lower relative humidities, nor will there be any great danger of slipping at high relative humidities unless accompanied by excessive temperature changes, in other words, the factor of safety in the ordinary belt rules is sufficient to take care of the effect of

changes in the relative humidity if the set up be made at a medium per cent of relative humidity.

Fourth. If a belt be set up at any relative humidity with a spring or gravity tightener, a load 50 per cent greater than

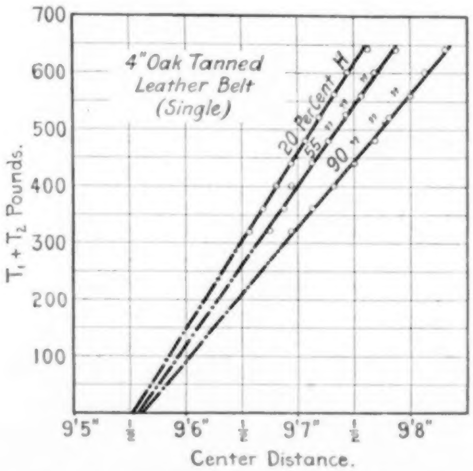


Fig. 3 Relation between $T_1 + T_2$ and Center Distance at Three Conditions of Relative Humidity. Horse Power Constant

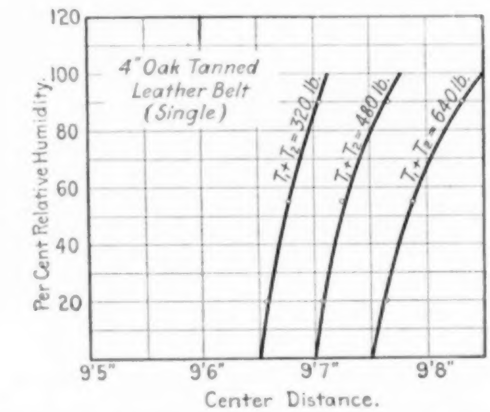


Fig. 4 Relation between Per Cent Relative Humidity and Center Distance at Three Conditions of $T_1 + T_2$. Horse Power Constant

the standard can be transmitted at either high or low humidity without danger of stretching the belt, slipping or excessive pressure on the bearings.

DISCUSSION

Geo. N. Van Derhoef (written). This paper is very interesting as it goes far in explaining some of the peculiar actions of belt drives, and it is to be hoped that it will attract general attention to the subject of belt tensions. It is strange that, in all the experimental work that has been done from time to time on the transmission of power by leather belts, this feature of effect of humidity should not have been investigated before.

The results again show the importance of using spring belt clamps in tightening belts, and also that when these are used attention should be given to temperature and relative humidity. It is quite likely that those who have not found the use of spring belt clamps all they expected may find the real explanation of the matter in the disregard of these two points. It is very common to take up belts at night or on Sunday. During the winter time the temperature and relative humidity are very apt to be markedly different from those during regular working hours.

The results also show the advantage of more frequent use of belt tighteners. The highest efficiency of drive and the maximum life of the belt can only be secured by keeping the slack side tension as low as possible. The injury to the belt by bending it in the reverse direction as it goes around the tightener pulley is practically negligible if the pulley is made of large diameter; in fact, this loss and that due to the friction of the tightener is far less than that due to the extra load on the bearings of the main shafts due to the belt without a tightener never being at its condition of minimum stress

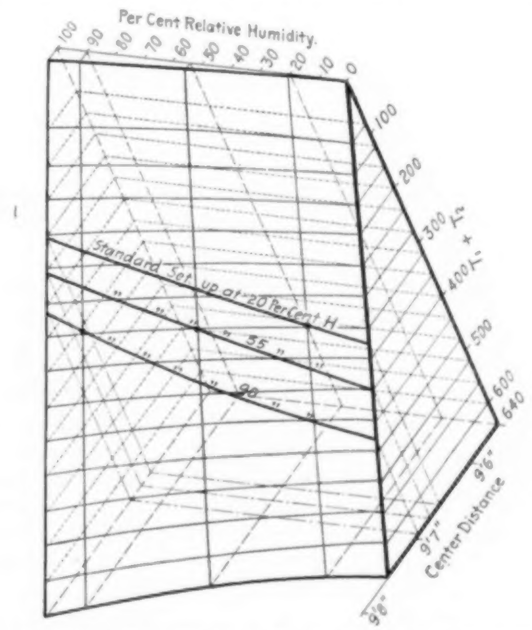


Fig. 5 Belt Performance Surface for an Oak Tanned Leather Belt 4 in. Wide, showing Relation between Center Distance, Sum of Tensions and Per Cent Relative Humidity

except just before taking up. A belt tightener is, however, of little value unless it is used to keep the belt just as loose as possible; it is very unfortunate that this important device was given the name of "tightener" instead of "loosener."

Nearly all belted electric generators and motors are arranged with sliding bases, and the belts used with them are considerably smaller than would generally be used with equal loads for other machinery.

The great success of the continuous system of rope transmission is due very largely to the fact that the tension can be kept at a minimum by means of the automatic tension carriage. While it is impossible to secure as favorable results with a belt drive, they can frequently be more or less approximated by the intelligent use of belt tighteners.

Carl G. Barth wrote that some fifteen years ago, while working for the Bethlehem Steel Company, he attempted to study the influence of humidity on the tensions of two belts in the shop, by daily plotting simultaneous humidity readings and readings of belt tension scales applied to the belts. However, due to the unlooked-for extraordinary variations in the

loads transmitted by these belts (at times they would carry heavy loads and again they would run idle for days at a time), no definite results were obtained, whereas he could not help believe that results of some value would have been secured if the belts had transmitted a fairly uniform load day and night.

Previously, the drop in tensions of two other belts had been studied during the winter months, when the shop was

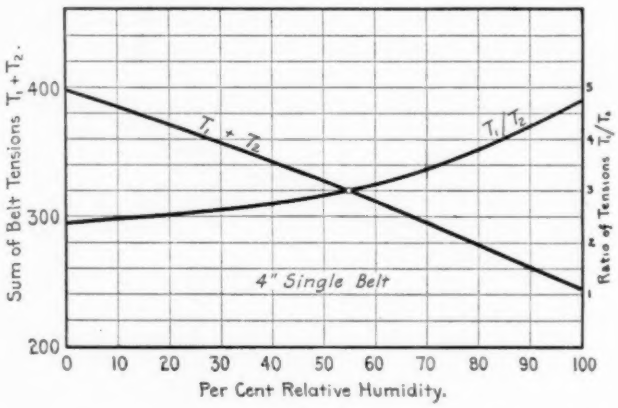


FIG. 6 EFFECT OF CHANGE OF HUMIDITY FROM 55 PER CENT. HORSE POWER CONSTANT

heated and both the temperature and the humidity thus kept within fairly small limits of variation. The results[1] were very satisfactory when the crudeness of the scales used was considered. The belts were re-tightened to a maximum tension when this had fallen to a minimum, which was carefully watched for by a system of inspection controlled by a tickler. A weakness in this has also been that on damp days old belts sometimes, and new belts frequently, reach the minimum tension between inspections, and thus at times require re-tightening during working hours, which is the very thing it was striven to avoid.

While the prescribed tension is so moderate that its rise due to a sudden drop in the humidity obtaining at a re-tightening will not do any great harm when the shaft and its bearings are properly proportioned and constructed, still it always appeared to him that some allowance should be made for the humidity, and he was of the opinion that the results obtained by the present experimenters would prove of value. However, he believed the results could be more readily applied if the experiments were repeated along the following slightly different lines:

Take a brand new first class belt and put it under an initial tension of 240 lbs. per square inch of cross section, over revolving pulleys transmitting no power. Measure its length under this tension while the humidity is kept constant. Keep this up until the tension has fallen to 120 lbs., or one-half the original amount. Re-tighten the belt over the same pulleys to 240 lbs. by cutting out the necessary fraction of its length, note this length, and proceed as before; repeat this procedure for at least one school year.

During the next two school years, repeat the process under different degrees of humidity, and with belts of the same size and make and preferably cut from the same roll as the first, or, if this is not feasible on account of expense, build and equip three separate rooms for the purpose and do all the work in one year.

Next, thoroughly impregnate the belts with some good belt dressing, such as Kling-Surface or Plomo, and repeat the experiments. It is claimed, and it is undoubtedly true, that belt dressings keep out the moisture to a considerable extent.

He was sure that the results to be obtained by a constant length of the belt under no load transmission would be more readily applicable in practice than would the results obtained by a constant load transmission with variable belt length.

F. G. GILBRETH thought we paid too much attention to the cost of the belt; it is to the cost of the up-keep of the belt and its effect on the achievement of the task of the worker that we should look, and he would like to know the effects of these experiments if carried on in practice on those two features.

WM. S. ALDRICH (written). Considering the number of variables and the atmospheric conditions to be controlled,

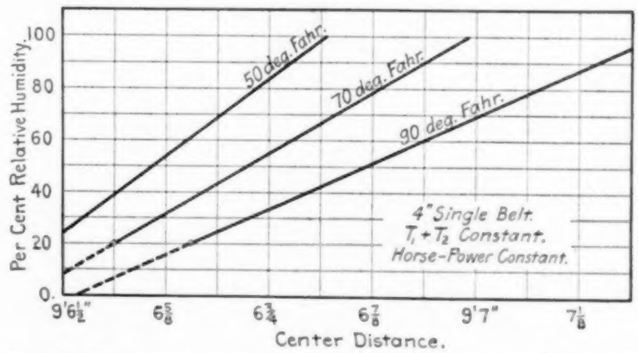


FIG. 7 RELATION BETWEEN CENTER DISTANCE AND RELATIVE HUMIDITY OF THREE DIFFERENT TEMPERATURES

the results are well worthy of attention in the every-day use of belting. Especially will this attention be possible in factories having heating and humidifying systems under more or less automatic control. The factors of temperature and humidity have already been found to influence shop production, and the cost of regulating them is more than compensated in certain lines and developments through increased economy and efficiency, and the enhanced general welfare of the workmen.

Setting up the belt, therefore, under the standard and maintained temperature and humidity of the shop, may come to be the order of the day. The 55 per cent relative humidity chosen by the authors for their standard test comparisons seems reasonable, but the 70 deg. temperature chosen as an accompanying standard shop temperature would be uncomfortable in practice. The best working temperature is still a mooted question and depends on the class of workmen, the kind of physical work and the humidity. The best range is probably a little under or over 60 deg., according to local circumstances. 60 or 62 deg. is also about the standard normal temperature for comparisons of engineering data, in English measures.

The barometric pressure must be taken into consideration in standardizing atmospheric conditions with regard to the

[1] Transmission of Power by Leather Belting, Barth, Trans. A. S. M. E., vol. 31, p. 43.

relative and absolute amount of moisture present. It is not unusual for this to range over two inches of mercury in the course of a day in very changeable weather. Were barometric readings taken throughout and all observations reduced to standards of comparison for the conditioned relative humidity selected?

A careful study of the comparative results at different temperatures, illustrated in Fig. 7, will show that it is probably the actual amount of moisture present in the air which most influences the stretch of the belt, and this is, therefore, the determining factor. In the diagrams, the scale values of the relative humidity may be interpreted as directly proportional to the actual moisture, assuming, however, that the barometric pressure was constant throughout the test.

From Meteorological Tables[1], the absolute amount of moisture present in the air under standard conditions, is:

Deg. fahr.	50	70	90
Gr. Troy	4.076	7.980	14.780

In other words, at the standard conditioning of the air in the shop of 55 per cent relative humidity, the actual moisture in the air, at the above temperatures will be 2.24, 4.39 and 8.13 grains, respectively. These weights are not quite in geometric progression, but they are sufficiently cumulative to suggest interesting comparisons. They show to what extent the belt can absorb moisture as the temperature rises—how hygroscopic it really is. In short, the belt seems to have almost unlimited capacity to absorb moisture as the temperature of the air rises, and in comparison with the accompanying equal increments of belt stretch under test.

The authors have well pointed out that the difficulties inherent with so many variables as naturally arise in belt testing indicated constant speed and constant load as prerequisites. It would be interesting to know how these latter might vary under varying humidity with constant center distance. It is this latter condition which is imposed on the belt in actual service. For precise work in certain driving operations, it may even be desirable to go to the expense of waterproofing the belt if this should prove feasible.

A. F. Nagle (written). This is a laboratory experiment and as such has an educational value, but its practical value may be questioned. Practical considerations, that is, men and materials, do not admit of too great refinements. Belt tensions should be adjusted by a mechanical engineer, with spring scales to guide him; but the operating mechanic will cut out an inch, more or less, if he finds a belt does not drive his machine. When the works are large enough to employ special men to attend all belts, something like the refinements alluded to in this paper may be carried out, but even then the practice is liable to fall into disuse.

The author should give the actual thickness of the belt used. Single thickness is not specific enough, for belts in the market vary nearly two to one in thickness.

W. W. Bird replied that if a belt is fitted up with a spring or gravity tightener, it practically adjusts itself, and a very material difference is made in regard to the up-keep. He was running a great many machines with an idler or spring arrangement to take up and tighten the belt, and this is done automatically; the arrangement not only lengthens the life of the belt, but also has a bearing on the question of up-keep. The question of a few dollars for a belt is nothing in comparison with the loss of use of a machine.

[1] Smithsonian Institution, Washington, D. C.

LAPS AND LAPPING

BY W. A. KNIGHT, COLUMBUS, O.

Member of the Society

AND A. A. CASE, COLUMBUS, O.

Non-Member[1]

The process of working down a surface by lapping, that is by wearing it down by the use of a loose-grained abrasive in connection with a lubricant was first applied in the grinding and polishing of precious stones. Later the process was applied to the working of hardened steel, and, from this, gradually extended to cover a wide variety of operations common to machine-shop practice.

There are two methods of using a surface lap which, for want of better definitions, will be termed the "wet" and the "dry" methods. In the wet method there is a surplus of oil and abrasive on the surface of the lap.

With the dry method, the lap is first charged by rubbing or rolling the abrasive into its surface. All surplus oil and abrasive is then washed off, leaving a clean surface, but one that has embedded uniformly over it small particles of the abrasive. It is then like the surface of a very fine file or oil stone and will cut away hardened steel that is rubbed over it.

The lubricants most commonly used for lapping are lard and machine oils, kerosene, and gasoline. Alcohol and turpentine have been recommended. It is well known that turpentine can be used to advantage when drilling hard steel.

Abrasive materials are usually emery, alundum, corundum, carborundum, or others of a similar kind, but sold under various trade names, as Crystolon, Axolite, Carbondite, etc. Diamond dust, ground glass, oil stone powder, and ground pumice stone are used for certain kinds of work.

The object of the experiments described was to secure, if possible, reliable data on:

a The relative efficiencies of the different abrasives.
b The relative efficiencies of different lubricants.
c The rate of cutting with laps made of cast iron, soft steel, and copper.
d The wear of the laps, compared one with the other and with the amount of steel ground off with each.
e The effect of pressure on the rate of cutting.
f The rate of cutting by the wet and the dry methods.

To carry out the experiments, a machine was constructed with which quantitative results could be obtained with various combinations of abrasive, lubricant and lap material.

The usual method was followed of keeping all variables constant except one, and, having determined the effect of that one, to proceed to the next. It developed, however, that some of the variables affecting the results were not entirely within control. Thus, for instance, the size of the grains of abrasives is one of the factors affecting the rate of cutting, and this factor is continually changing during the process.

Again, when using volatile liquids, like gasoline, turpentine, and alcohol, fresh additions had to be made to the plate to make up the loss from evaporation.

[1] Instructor, Ohio State Univ.

Presented at the Spring Meeting of the Society, June 1915. Complete paper may be obtained without discussion; price 15 cents to members; 30 cents to non-members.

Thorough precaution was taken to reduce all uncertain factors to the lowest possible limit and confidence is felt that the results are well within the limits of practical accuracy.

The machine which was designed and used for these tests is shown in Fig. 1. The horizontal shaft *B*, driven by motor *A*, transmits motion through spiral gears to two vertical shafts *C* and *D*. Shaft *C* carries the lapping plate at its upper end and shaft *D* the slotted crank disk *E*, by means of which, and the connecting rod *F*, the specimen holder *H* is made to reciprocate between the center and outer edge of the lapping plate. The motions of the lapping plate and specimen holder cause the latter and its specimen to follow a path relative to the plate like that shown in Fig. 2.

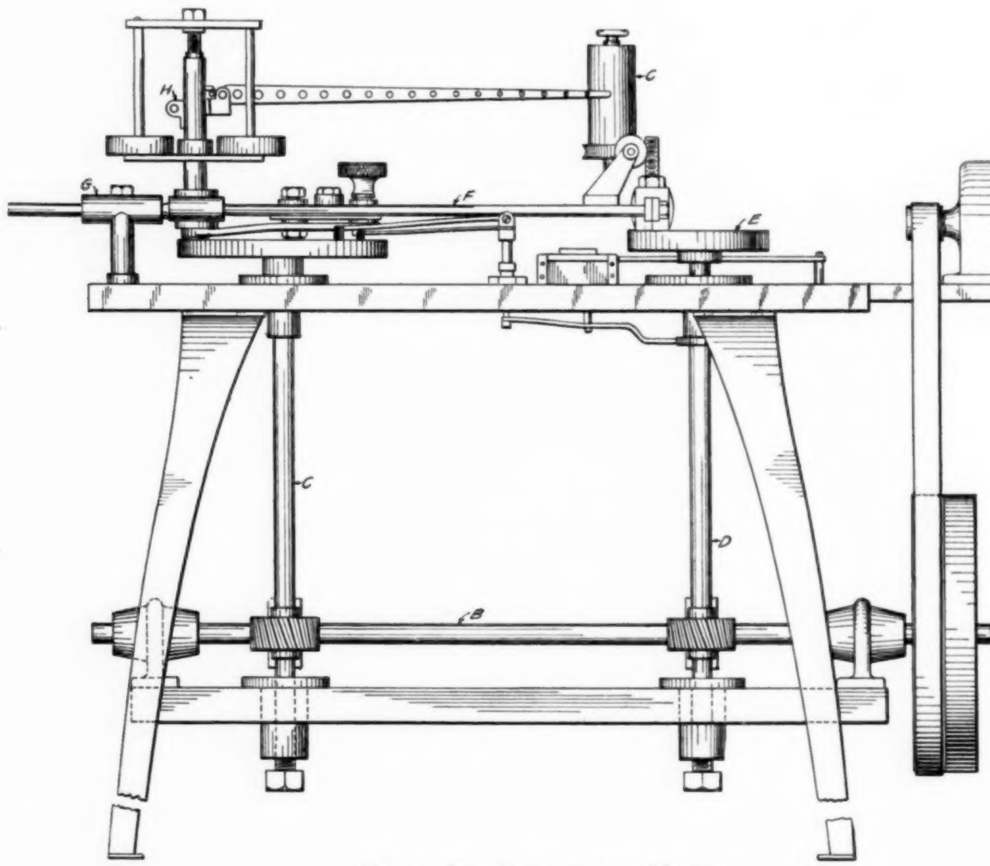


FIG. 1 SIDE ELEVATION OF MACHINE

As at first constructed the machine was autographic, but too many uncertainties were introduced by the friction of the pencil and other conditions and this feature was finally abandoned.

The specimen holder is shown in section in Fig. 3. The specimen is held in the hardened steel bushing *o* in end of lever *l*, which receives its motion through connecting rod *f* to which it is attached by studs *m* and *n*. The specimen is held against the lapping plate by the pressure of the weights, shown in the figure, transmitted to the specimen through the yoke *e*, screw *s* and pin *j*. These parts are supported by a tube *a* held by the split block *b* which in turn is clamped to the connecting rod *f*.

The nut *d*, through which passes the screw *s*, is of tool steel, hardened, ground and lapped to a smooth working fit in the tube. At *k* is a hardened steel plug, which is also a smooth working fit in the tube. This plug has a conical seat at each end in which bear the tapered ends of screw *s* and pin *j*. A perfectly free vertical motion is obtained, whereby the weights can follow up the wear of the specimen with practically no friction.

The bushing *o* which carries the specimen is counterbored in order that any side thrust may be brought as near the lower surface of the specimen as possible. To move the specimen from under the tube for examination, or removal, the knurled nut *n* is loosened, thus permitting the arm *l* to to be turned about the stud *m*.

The lapping plate is shown in section in Fig. 4. The lap surface is at *A*. A gray iron plate, cast originally ½ in. thick and finished down to ⅜ in. thick, is held to the lower plate *B* by means of screws. The outer rim *C* is also fastened by screws and is removable.

The copper and steel laps were built up the same way. The copper plate was made of plate copper ¼ in. thick; since this was too thin to be tapped into, it was secured to the cast plate by means of solder. The steel plate was made of fire-box steel ¼ in. thick and secured in the same manner as the copper plate. The surfaces of all laps were finished by grinding.

The distributor, or wiper, is an important feature of the machine. It is shown in detail in Fig. 5. It was essential that there be a uniform distribution of the charge of abrasive over the entire surface of the plate. Centrifugal force was depended upon to work the charge from the center of

the plate outward, and a wiper, *T*, consisting of a strip of wood resting on the plate and inclined at an angle of 15 deg. to a radial line from the center, was counted on to shear the charge back toward the center. Motion was given to the wiper through the medium of an eccentric *R* placed on the shaft *D*. To prevent an accumulation of part of the charge around the inner surface of the outer ring, a small auxiliary wiper was placed as shown at *Q*.

The test specimens were of hardened tool steel, of 5/8-in. drill rod. Fifty-five pieces 1/2 in. long were cut from the same bar and numbered consecutively. They were hardened by heating in the muffle of a regulated gas furnace, and quenching in clear salt water.

Three abrasives were selected as being representative of those on the market. These were Naxos Emery, from the Safety Emery Wheel Co., Springfield, O.; Carborundum, di-

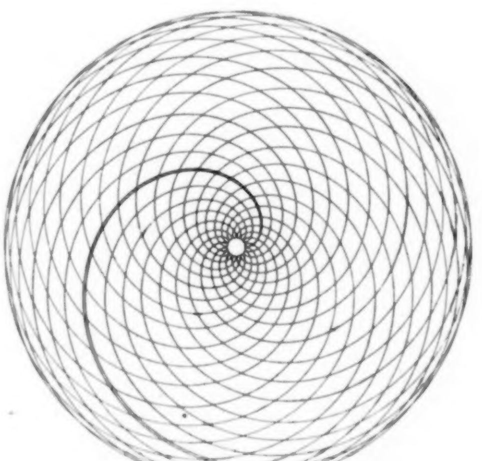


FIG. 2 OUTLINE TRACED BY SPECIMEN ON LAP

rect from the Carborundum Company, Niagara Falls, N. Y., and Alundum, from the Norton Company, Worcester, Mass. All the tests were carried out with abrasive No. 150. Each of the abrasives was tried with seven different lubricants, five different pressures, and three different laps. The lubricants were lard oil, machine oil, kerosene, gasoline, turpentine, alcohol, and soda water.

Starting a series of tests, say with emery as the abrasive and with cast iron lap, the first test was made with lard oil and with a pressure of 5 lb. per sq. in. on the specimen. The pressure was then increased to 10 lb. per sq. in., other conditions remaining the same, and another run made. The pressures were then increased to 15, 20, and 25 lb., giving a group of five runs with lard oil.

Machine oil was then substituted for lard oil and a like group of tests made, after which tests were made with the other lubricants in the same way. This gave for cast iron-emery a series of 35 tests.

Carborundum was next substituted for emery and the same number of tests repeated. This was followed by a like series with alundum, making the total number of tests with cast iron lap 105.

The cast iron lap was then replaced by one of steel and a second series of 105 tests run with the steel lap. This was followed by a like series with the copper lap.

The conditions of the tests are described fully in the paper.

The log of a single test is shown in Fig. 6, while Fig. 7 shows the plotted results of a typical individual test of the cast iron-emery series. A summary of all the results of tests is given in Table 1.

TABLE 1 SUM OF AMOUNTS GROUND FROM SPECIMENS WITH PRESSURES OF 5, 10, 15, 20, AND 25 LB. PER SQ. IN.

		Machine Oil	Lard Oil	Kerosene	Gasoline	Turpentine	Alcohol	Soda Water	Total
Cast Lap	Emery	1320	1673	3324	3955	2336	2392	3105	18105
	Alundum	1849	2313	3687	4291	3230	3251	3112	21733
	Carborundum	2825	3340	4230	4520	4458	4427	3873	27673
	Total	5994	7326	11241	12766	10024	10070	10090	67511
Steel Lap	Emery	1744	2460	2720	3034	2560	2608	2839	17965
	Alundum	1800	2537	3622	3627	3400	3388	3338	21712
	Carborundum	4199	4649	3805	3980	3983	3527	4045	28188
	Total	7743	9646	10147	10641	9943	9523	10222	67865
Copper Lap	Emery	3250	3454	3756	3813	3598	3961	3780	25612
	Alundum	3971	4065	3763	3960	4171	4097	4472	28499
	Carborundum	4148	4540	3692	3724	4251	4081	4210	28646
	Total	11369	12059	11211	11497	12020	12139	12462	82757
	Grand total for each lubricant	25106	29031	32599	34904	31987	31732	32774	

In Fig. 8 is given a typical series of characteristic curves obtained by summing up the ordinates of the individual test curves for the different lubricants, abrasives and lap materials. For instance, the gasoline curve in this figure is obtained by summing up all the ordinates of the five curves in Fig. 7.

Lubricants. The action of the different lubricants presents an interesting study. The same lubricant acts differently with the different abrasives and again differently with different laps.

Taking the results of the emery-cast iron series of tests alone, as shown in Fig. 8, it would seem that the change in the viscosity and lubricating properties would offer a reasonable and fairly complete explanation of the difference in their behavior. Gasoline, which is lowest in these respects, has the highest rate of cutting, which is well maintained, being nearly as high at the end of 4000 rev. as at the beginning. Next is kerosene, the rate of cutting of which is high, but which shows slightly more of a decreasing rate as the end of the run is approached. Soda water is below kerosene, but maintains its rate of cutting more like gasoline.

The paper here includes a detailed consideration of the results from various lubricants. The following is a summary:

Lard and Machine Oil. For these lubricants, it is to be observed:

a That in tests under all conditions, their curves are of the same form and follow each other closely.

b That lard oil without exception gives the higher rate of cutting.

c That in general the initial rate of cutting is higher than with the lighter lubricants, but falls off more rapidly as the run proceeds.

d That both the highest and lowest results of the whole number of tests were obtained with these two lubricants. The lowest with machine oil, emery-cast iron lap, with lard oil a little above it; the highest with lard oil, carborundum-steel lap, with machine oil a little below it.

Table 2 shows this progressive increase in the values obtained with the different combinations:

TABLE 2 AMOUNT GROUND FROM SPECIMEN WITH MACHINE AND LARD OIL FOR THE DIFFERENT COMBINATIONS OF LAP AND ABRASIVE

Lap	Abrasive	Machine Oil	Lard Oil
Cast Lap	Emery	1320	1673
	Alundum	1849	2313
	Carborundum	2825	3340
Steel Lap	Emery	1744	2460
	Alundum	1800	2557
	Carborundum	4199	4649
Copper Lap	Emery	3250	3459
	Alundum	3997	4065
	Carborundum	4148	4540

Gasoline and Kerosene. On the cast iron lap gasoline shows the highest results of any of the lubricants tested. It is not so good on copper and still less so on steel. Taking into account all three abrasives, its relative value on the different laps is as follows:

Cast iron 127 Copper 115 Steel 106

Kerosene shows more nearly the characteristics of gasoline than of the heavier oils. Like gasoline, it gives the best results on cast iron and the poorest on steel. It does not work so well with carborundum on the copper lap.

Turpentine and Alcohol. There is no evidence to show that turpentine possesses any superior advantage over the other lubricants. On any lap it does good work with carborundum. With emery it does fair work on the copper lap, but with emery on the cast iron and steel lap it is distinctly inferior.

Alcohol in some ways acts very much like turpentine. It also gives the lowest results with emery on the cast iron and steel laps.

Soda Water. Soda water gives reasonably good results with almost any combination of lap and abrasive. While it is seldom the best, it is never the worst. It does its best work on the copper lap and poorest on steel, although there is not much difference between its work on the cast iron and steel. On the cast iron lap it does better work than machine or lard oil, but not so good as gasoline.

Abrasives. It may be well to call attention to the fact that emery and alundum are similar abrasives, both being aluminum oxides of the form Al_2O_3. Emery is a natural product, more or less contaminated with iron or other impurities. Alundum is an artificial product and, in general, of greater purity than the natural product. Carborundum, on the other hand, is an entirely different material, being a carbide of silicon, SiC. Naturally, then, emery and alundum might be expected to show more nearly the same characteristics, while carborundum would deviate more or less from them.

The curves in Figs. 9 and 10 show the rates of cutting for the three abrasives with cast iron lap, and with machine oil and lard oil respectively. The paper gives similar sets of curves for all the different combinations of lap and lubricant.

The total amounts of steel ground from the specimens with each abrasive are given in Table 3.

TABLE 3 AMOUNTS IN MILLIGRAMS GROUND FROM SPECIMENS WITH DIFFERENT COMBINATION OF LAP AND ABRASIVE

Lap	Abrasive	Amount	Lap	Abrasive	Amount	Lap	Abrasive	Amount
Cast Lap	Emery	18105	Steel Lap	Emery	17965	Copper Lap	Emery	25612
	Alun.	21733		Alun.	21712		Alun.	28499
	Carb.	27673		Carb.	28188		Carb.	28646

The evidence all the way through tends to the conclusion that there is for each different combination of lap and lubricant a definite size grain of abrasive that will give maximum rate of cutting.

The hardness of the various laps, as determined by the research department of the Westinghouse Electric and Manufacturing Co., was as follows:

By the brinell method
Cast iron 109 Steel 87 Copper 43.6

By the scleroscope
Cast iron 28 Steel 18 Copper 5

A comparison of the three laps with all combinations of abrasive and lubricant is given in twenty sets of curves. Two sets are shown in Figs. 11 and 12.

Figures are given to show that, with the proper abrasive

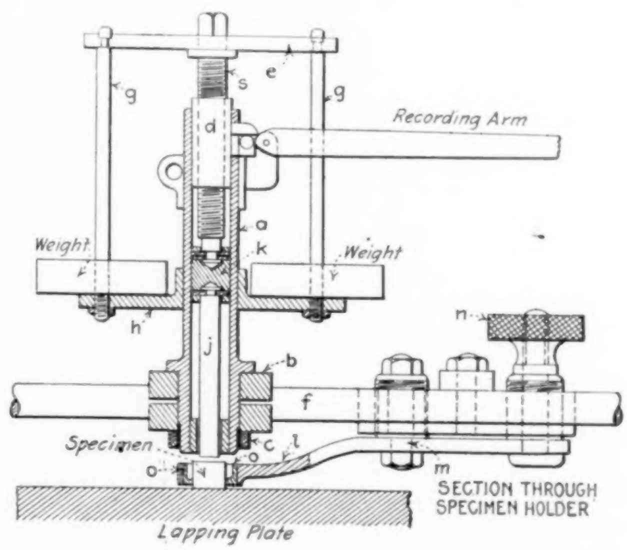


Fig. 3 Section through Specimen Holder

and lubricant, steel and cast iron are equally as good (for all practical purposes) as copper.

Wear of Laps. One of the remarkable facts brought out was the great difference in wear of the laps. The wear on all laps was about twice as fast with carborundum as with emery, while with alundum the wear was about one and one-fourth times that with emery. On an average the wear of the copper lap was about three times that of the cast lap. Table 4 shows this clearly.

TABLE 4 AMOUNTS GROUND FROM THE LAP SURFACE FOR EACH 100 MILLIGRAMS GROUND FROM THE SPECIMEN

	Emery	Alundum	Carborundum	Total
Cast iron	81.2	118	158	357.2
Steel	114	149	190	453
Copper	233	295	410	938

As regards permanence of form, cast iron is altogether better than either steel or copper, and taking into account its first cost and that with proper abrasive and lubricant its rate of cutting is practically as good as copper or steel, it is far and away the best lap material.

From results obtained on the wear of the laps, it is evident that the theory of the lodgment of the abrasive in the softer lap surface is not well founded. The action appears to be more mutual between the surfaces.

Within the limits of the pressures used; that is, up to 25 lb. per sq. in., the rate of cutting is practically proportional to the pressure.

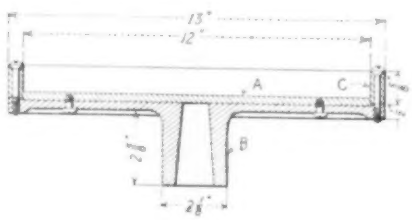


Fig. 4 Section through Lapping Plate

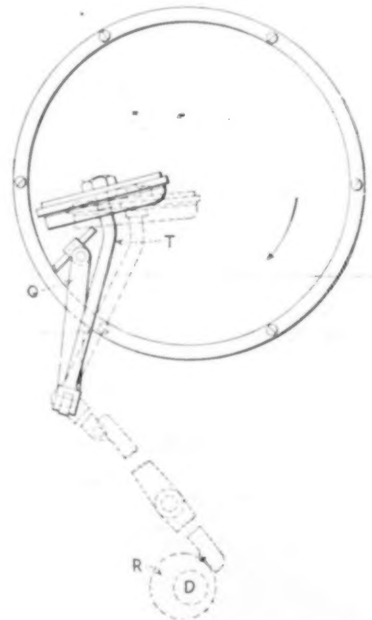


Fig. 5 Plan of Distributor

The higher pressures, 20 and 25 lb. per sq. in., did not do so well on the copper lap as on the others. There was some evidence tending to show that for this lap the practical limits of pressure had been reached.

Of the 63 combinations tried out, the 15 giving best results are presented in Table 5.

Dry Lapping. Experiments on dry lapping were carried out on the cast iron, steel and copper laps and also on one of tin made expressly for the purpose.

Carborundum alone was used as the abrasive and a uniform pressure of 15 lb. per sq. in. was used on the specimen throughout the tests. In dry lapping much depends on the manner of charging the lap.

The results of these tests are shown in curves in the paper and are tabulated in Table 6. Fig. 13 gives one set of curves.

TABLE 5 COMPARATIVE VALUES OF THE BEST COMBINATIONS, TAKING EMERY-CAST IRON LAP AND MACHINE OIL AS UNITY

Carborundum—Steel lap —Lard oil	3.52
Carborundum—Copper lap—Lard oil	3.44
Carborundum—Cast lap —Gasoline	3.42
Alundum —Copper lap—Soda water	3.39
Carborundum—Cast lap —Turpentine	3.37
Carborundum—Cast lap —Alcohol	3.35
Alundum —Cast lap —Gasoline	3.25
Carborundum—Copper lap—Turpentine	3.22
Carborundum—Cast lap —Kerosene	3.20
Carborundum—Copper lap—Soda water	3.19
Carborundum—Steel lap —Machine oil	3.17
Alundum —Copper lap—Turpentine	3.15
Carborundum—Copper lap—Machine oil	3.14
Alundum —Copper lap—Alcohol	3.10
Carborundum—Copper lap—Alcohol	3.09

The greatest difference due to different charging is shown by the tin lap. When abrasive No. 150 is rolled into its surface the cutting is about two and one-half times as fast as when the same abrasive is rubbed in. Also it is about three times as fast as when abrasive "F" is rolled, and six times as fast as when "F" is rubbed in.

TABLE 6 RESULTS OF TESTS ON DRY LAPPING

		Revolutions			
		100	200	300	500
	Lap	Milligrams ground from specimen			
Carborundum No. 150 lap charged by rolling	Cast	3.6	6	7.6	8.6
	Steel	10.3	13	15.3	16.6
	Copper	11.3	16.3	19	23.3
	Tin	18.6	25.6	30.6	39
Carborundum No. 150 lap charged by rubbing	Cast	2	3.3	4	5
	Steel	6.6	8.6	9.6	11
	Copper	6.6	9.6	11.6	13.6
	Tin	7.3	10.3	12.3	15.3
Carborundum "F" lap charged by rolling	Cast	8.6	12.6	14.6	16.6
	Steel	6.3	8.3	9.3	10.6
	Copper	6	8	9.6	11
	Tin	7	9.3	10.3	12
Carborundum "F" lap charged by rubbing	Cast	2.6	5	6	7
	Steel	5	7	8	9
	Copper	3	5	6.6	8.6
	Tin	2	4	5	5.3

It thus appears that with soft and ductile materials like copper and tin the best results are to be obtained by rolling a comparatively coarse abrasive into the surface, but that with a harder and more brittle material like cast iron a finer grade should be used.

A comparison between the wet and dry methods is more or less unsatisfactory. In dry lapping the rate of cutting decreased rapidly after the first 100 revolutions of the machine—much more rapidly than with the wet method. It seems no more than fair, then, in making comparisons to consider the amounts ground off during the first 100 revolutions. Further, the highest result obtained with each lap is taken as the basis of comparison. With these data, it is found that with the tin lap, charged by rolling carborundum No. 150 into the surface, the rate of cutting, dry, approaches that of the wet. With the other laps, the rate for dry is about $\frac{1}{2}$ that of the wet. Table 7 exhibits this.

It may be of interest to know the rate of cutting in linear measure. With the size of specimen used, the removal of 39 milligrams represented a length of 0.001 in. With a pressure of 15 lb. per sq. in., the average of the best results was just about 22 mg. for 100 revolutions of the machine. The length of path traversed by the specimen was 36 in., or 3 feet per revolution. Hence, the specimen moved over the lap a distance of 300 ft. to have ground from its surface 0.00056 in., or 0.00019 in. for 100 ft. of travel over the lap surface.

With dry lapping on the tin lap, the best result was 18.6 mg. for 100 revolutions, which gives 0.00016 in. per 100 ft. of travel. This is with a pressure of 15 lb. per sq. in. on the specimen, and, of course, with a higher pressure a greater amount would be ground off.

Test No. 92 Date 3-12-13 Observer - KNIGHT

ABRASIVE - Emery - Grade 150 - Lubricant M. Oil Pressure 15 lbs.

Reading of Counter	Reading of Counter	Revolutions	Weight beginning of run	Weight end of run	Weight ground off
21000	21500	500	19330	19240	90
	22000	500		19186	54
	23000	1000		19139	47
	24000	1000		19110	29
	25000	1000		19090	20
			19330 19090		90 144
			240		191 220
					240

FIG. 6 LOG OF A TYPICAL TEST

The main facts, as developed by the investigations and deductions therefrom, are summarized as follows:

a The initial rate of cutting is not greatly different for the different abrasives.

b Carborundum maintains its rate better than either of the others, alundum next, and emery the least.

c Carborundum wears the lap about twice as fast, and alundum $1\frac{1}{4}$ times as fast as emery.

d There is no advantage in using an abrasive coarser than No. 150.

e The rate of cutting is practically proportional to the pressure.

f The wear of the laps is in the following proportions:
Cast iron 1.00 Steel 1.27 Copper 2.62

g This wear is inversely proportional to the hardness by the brinnel test.

h In general, copper and steel cut faster than cast iron, but where permanence of form is a consideration, cast iron is the superior metal.

TABLE 7 COMPARISON OF WET AND DRY LAPPING; PRESSURE, 15 LB.; ABRASIVE, CARBORUNDUM; 100 REV. OF MACHINE

	Best results with			
	Cast Lap	Steel Lap	Copper Lap	Tin Lap
Wet	20	24	22	....
Dry	8.6	10.3	11.3	18.6

i Gasoline and kerosene are the best lubricants to use with cast iron lap; kerosene, on account of its non-evaporative qualities, being first choice.

j Machine and hard oil are the best lubricants to use with copper or steel lap. They are least effective on the cast lap.

k For all laps and all abrasives (of those tested), the cutting is faster with lard oil than with machine oil.

l Alcohol shows no particular merit for the work.

m Turpentine does fairly good work with carborundum, but in general is not as good as kerosene or gasoline.

n Soda water compares favorably with other lubricants. Taken as a whole, it is slightly better than alcohol and turpentine.

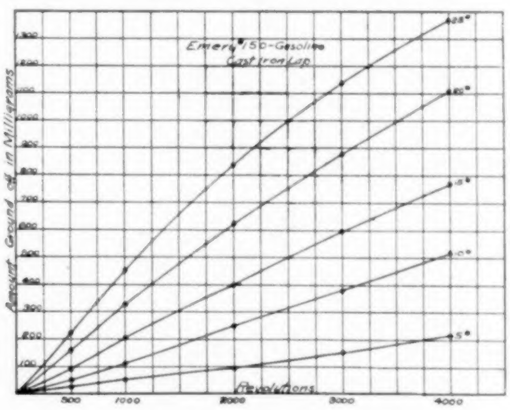


FIG. 7 CHARACTERISTIC CAST IRON-EMERY TEST

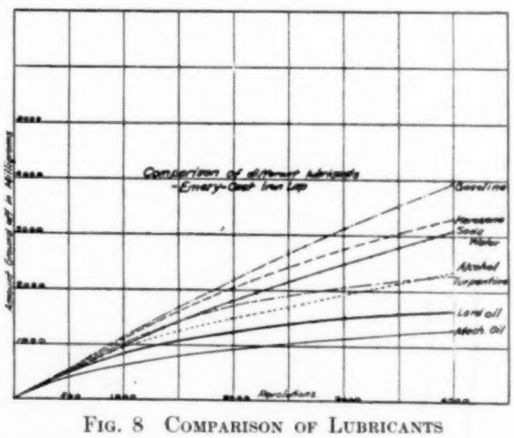


FIG. 8 COMPARISON OF LUBRICANTS

o Wet lapping is from 1.2 to 6 times as fast as dry lapping, depending on material of the lap and manner of charging.

In an appendix is given a rather full bibliography of the subject of lap and lapping.

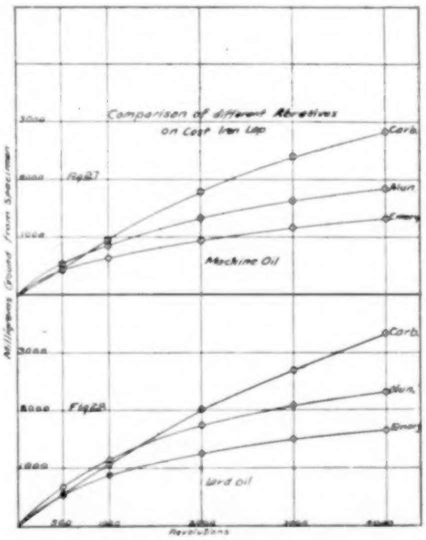
DISCUSSION

CHARLES E. GILLETTE (written). Except for the work of Schlesinger at Charlottenburg, in 1906, for the Prussian Department of Commerce and Labor, very little of a purely scientific character covering grinding has been published. Professor Alden in his paper, Operation of Grinding Wheels in Machine Grinding, presented before this Society last De-

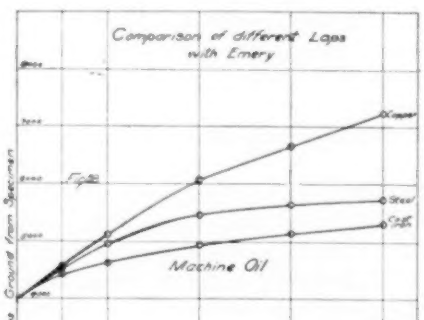
cember, sets forth the controlling factors governing the action of abrasives when used in the form of grinding wheels; the principles brought out in his paper will form the basis of much valuable experimental work in the future.

The authors are, therefore, to be complimented for their addition to the small store of available data on the action of abrasives under actual operating conditions.

In lapping, as in other operations requiring the use of abrasives for the removal of material, rule of thumb methods have predominated, and such information as has been obtained cannot be said to have been based upon scientific investigations.



FIGS. 9-10 COMPARISON OF ABRASIVES



FIGS. 11-12 COMPARISON OF LAPS

Lapping, in the sense accepted by our best mechanics, infers the use of a perfect master surface to obtain upon a piece of work a level surface and a certain finish or accuracy of dimensions compatible with the purpose for which the lapped piece is to be used. In tool making, where accurate duplication of parts is necessary, lapping reduces the chance for wear and insures the maintenance of standards. In optical work lapping is resorted to for the purpose of obtaining as near as possible absolutely accurate dimensions, together with a finish or polish that will not interfere with the passage of light waves.

For roughing or blocking down, that is, where the work has not been ground on a surface grinding machine previous to the lapping operation, a different method is used. It would seem, therefore, that while the authors have conducted tests along the methods used in blocking down, the information obtained regarding the action of the abrasives could not be successfully utilized in actual lapping practice.

The point which is most forcibly brought out is that car-

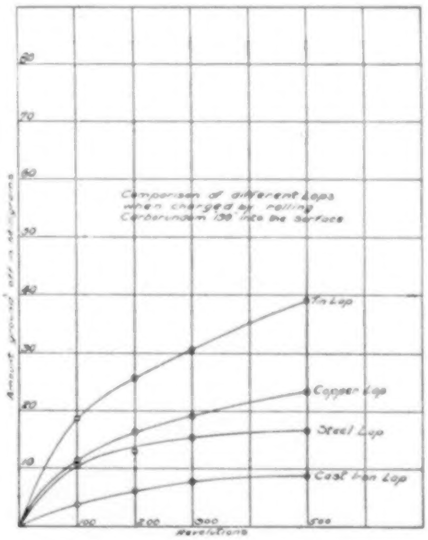


FIG. 13 TYPICAL CURVES OF DRY LAPPING TESTS

bide of silicon acts more efficiently on hardened steel than do the aluminous abrasvies. One of the absolute laws of grinding is that aluminous abrasives act more efficiently on materials of high tensile strength, like steel and its alloys, while the carbide of silicon is most efficient on materials of a low tensile strength, such as cast iron, brass, bronze, etc. This is due to the physical properties of the two abrasives, the one being very hard and tough while the other is slightly harder, but relatively quite brittle.

However, lapping may bring into action different properties of the abrasives than is obtained in the solid abrasive wheel. In lapping, the grains are under compression, while in a grinding wheel each grain on the grinding surface might be considered a cantilever subjected to sudden loading at its end, repeated with great frequency.

Considering that the action of an oilstone is like that of a lap which has been charged by either having the abrasive rubbed or rolled into it, the results of a series of tests conducted by the Norton Company may be of interest. The object of these experiments was to compare the cutting qualities of oilstones made of aluminous and carbide of silicon abrasives. The only variable was the composition of the oilstones—there being one aluminous and three carbide of silicon abrasives used. The lubricant was a light grade of machine oil.

A universal grinding machine was used in the test, a special attachment being devised to hold the test piece—a hardened steel chisel with a $1\frac{1}{2}$ in. blade. The oilstone was

clamped to the table of the machine and traversed under the chisel blade at a fixed velocity. The chisel was so prepared that the surface in contact with the oilstone measured $1\frac{1}{2}$ by $\frac{1}{2}$ in.

A pressure of 40 lb. per sq. in. was selected as giving sufficiently accurate results. It was found necessary to use an excessive amount of lubricant to prevent the oilstone from loading or filling up before the end of the test. The chisel blade was traversed a distance of 500 ft. across the oilstone, the stone then being turned over and a run of 500 ft. being made on the other side of the same stone.

While the testing apparatus was not as nicely adjusted as the machine described in the paper, the results obtained were considered sufficiently accurate for commercial purposes. A summary of them follows: Milligrams removed from chisel per 1000 ft. travel across the oilstones

Alundum	145
Carbide of Silicon No. 1	33
Carbide of Silicon No. 2	42
Carbide of Silicon No. 3	90

These results indicate, without question, that the aluminous abrasive cuts the hardened steel tool much faster than carbide of silicon when used in the form of an oilstone. The size of abrasive used on the oilstones corresponds very closely to the sizes used by Professor Knight in his test.

A very interesting question has been brought out by these tests which ought to be given further consideration. Is there a certain "critical point," so-called, at which all abrasives have an equivalent cutting action under identical test conditions, and either side of which each type of abrasive has its own distinctive field? In other words is carbide of silicon in the coarse sizes more efficient on materials of a low tensile strength and in the fine sizes more efficient on materials of a high tensile strength than aluminous abrasives? A theoretical consideration of the physical properties of the two types of abrasives will show why the action of loose abrasive grains as used in rough lapping may be considerably different than when they are held more or less solidly in a body, such as a charged lap, oilstone or grinding wheel.

The U. S. Bureau of Standards places the hardness of carborundum at 9.6, alundum 9.4 and emery at approximately 9 on Mohr's scale. Carborundum, a carbide of silicon abrasive, is brittle. Alundum and emery, aluminous abrasives, are very tough in comparison. Tests upon grains of emery, alundum and carborundum show the relative compressive strength to be approximately as 1.00: 1.8: 2.0. This shows that emery would break down under straight compression first, alundum second and carborundum last.

Professor Knight states "emery appears to be more brittle and passes through the change quicker than the others, with alundum next and carborundum the least susceptible to such a change." Thus it would seem that in blocking down, where the abrasive grains are compressed between the lap and work, the ability to resist crushing is a more important factor than the actual hardness or toughness. Emery, being relatively weaker in compression, breaks down into the impalpable sizes faster than the other abrasives, hence does less effective work during the period of test. This presupposes that the coarser sizes of abrasives cut the faster.

With the abrasive held in a ceramic body, such as an oilstone or grinding wheel, the tougher aluminous grains stand up under the shearing action of the test piece longer than the brittle carbide of silicon abrasives. The tougher abrasive grains maintain their cutting edges and remain sharp longer than the brittle abrasives, which soon dull over, become glazed and stop cutting.

An examination of the curves in the paper shows that there is no great variation in the initial rate of cutting of any of the abrasives when tried under similar conditions. Any such slight variation might well be caused by a microscopic change in test conditions. Even with the utmost care it is almost impossible to obtain identical conditions in such a test. The wide variation in results obtained in wet and dry lapping or from charging the laps by rubbing or rolling shows the wide limit of the possible results that might be obtained. In testing solid abrasive wheels, the same wide variations are experienced with wet and dry grinding, slight variations in pressure, method of preparing the grinding surface (dressing the wheel) for test, the feeds and speeds used.

It is possible that the slight differences in the sizes of the abrasive grains obtained from the various manufacturers would have an influence on the results as the size of the holes in screens of a certain mesh varies according to the size of the wires used in the screen.

For lapping, a round solid grain which will stand up and maintain its shape is to be preferred to one which will break down and present new sharp cutting points to the work. Such a grain would cut the work being lapped, and in cutting would produce scratches which would be difficult to elminate.

Commercially only the abrasive flours, so-called, are employed for lapping, in general the size known as FF being the coarsest used. The diameter of a grain of FF averages 0.002 inches and the material is too fine to screen in the usual way. In order to obtain a uniform product, it is necessary to hydraulically classify the abrasive flours.

One of the largest small tool manufacturers in this country having experimented with all abrasives available for lapping found 65F alundum to be the fastest cutting abrasive material for his purpose. Cast iron laps are used with lard oil as a lubricant. The carbide of silicon flours were found to cut very fast, but at the same time it was impossible to eliminate scratches so deep that they could not be removed under commercial conditions. The amount of wear on the lap increased noticeably at the same time by the use of the carbide of silicon abrasive.

It would seem that, if carbide of silicon grain is more efficient than the aluminous abrasives in lapping hardened steel, then it would be more universally employed in place of the emery and alundum flours which seem to hold the field at present. It may be that the action of loose abrasive grain is materially different than when held in a body; however the cases are few, in actual practice, where carbide of silicon is more efficient than alundum when working on materials of a high tensile strength. With this exception, the authors have shown the action of loose grain abrasives in the fine numbers to be similar to the coarser sizes when used in solid wheel form.

The amount of time and patience necessary to obtain data for this paper can only be appreciated by those who have been engaged along similar lines. Professor Knight and Mr. Case are to be commended for the care and detail shown in their paper.

THE SURFACE CONDENSER

BY C. F. BRAUN, SAN FRANCISCO

Associate-Member

This paper analyzes the functions of the surface condenser, presents briefly the fundamental principles governing design, discusses rational ratings, and compares typical commercial designs.

The primary functions of a surface condenser are to reduce the back pressure on the exhaust side of a steam prime mover; to conserve and return to the steam generator, in the water of condensation, as many heat units as possible; and to remove air from the feed water, thus reducing pitting of boilers. In accomplishing these results the condenser must handle four separate fluids: steam, air (including other non-condensable vapors), water of condensation, and cooling or circulating water. As the desirable state of these several fluids is not the same, the problem at once becomes a complicated one. Briefly, the conditions to be approached are:

Steam should enter the condenser, be conducted freely to all parts with least possible resistance, reduced to the lowest practicable temperature (and consequently pressure) and converted into water.

Air, a non-conductor, should be rapidly cleared from the heat-transmitting surfaces, collected at suitable places, practically freed from entrained water and water vapor, and cooled to a low temperature for removal at minimum volume, with consequent least expenditure of mechanical energy.

Condensate should also be rapidly cleared from the heat transmitting surfaces, freed from air, collected at suitable points for removal, and returned to the steam generator at the maximum practical temperature.

Circulating water should pass through the condenser with least friction, deposit a minimum amount of precipitated chemicals or debris, and absorb a maximum amount of heat.

The main principle of design of the condenser is the transference of heat from the steam through the dividing surface to the cooling water. The transfer per unit of area or of size is a measure of the efficiency of the apparatus and is directly proportional to the temperature difference or head. The temperature of the water increases during its passage through the condenser, and that of the steam decreases; it is therefore necessary to obtain mean values for temperature differences. A simple arithmetic mean is not correct, but the following formula, developed mathematically by Grashof, has repeatedly been proven accurate and is almost universally adopted.

$$M = \frac{D_1 - D_2}{\log_e \dfrac{D_1}{D_2}} \ldots\ldots\ldots\ldots [1]$$

where

M = mean temperature difference

D_1 = temperature difference between fluids at beginning $= T S_1 - T W_1$

D_2 = temperature difference between fluids at end $= T S_2 - T W_2$

$T S_1$ = initial temperature of steam

$T S_2$ = final temperature of steam

$T W_1$ = initial temperature of circulating water

$T W_2$ = final temperature of circulating water

It is commonly assumed that $T S$ is constant throughout the condenser, by which this formula reduces to

$$M = \frac{T W_2 - T W_1}{\log_e \dfrac{T S - T W_1}{T S - T W_2}} \ldots\ldots\ldots\ldots [2]$$

Since the frictional drop through the steam space of a condenser is usually 0.5 in. or more, representing with high vacuums a temperature difference of say 10 deg. fahr., it is evident that the use of formula [2] for applying to large condensers data obtained on smaller ones, or for analyzing the performance of a condenser or various sections of a condenser, will lead to serious errors.

With any given set of temperature values the mean temperature difference can be varied in only one way, namely, by arrangement of heating surfaces. These must be such as to produce counter-current flow, the circulating water entering where the steam is coolest and leaving where it is hottest.

Transfer of heat through a unit of condenser tube area per unit of mean temperature difference was early recognized as varying greatly under different conditions, the most apparent variation being an increase with increase of water velocity. Many experimenters have carried out extensive and careful tests to determine values of this heat transfer and a common formula is $H = K V^{1/2}$. That such a formula is fundamentally incorrect and misleading is at once apparent when it is considered that certain resistances to heat flow, namely, that of the tube and that on the steam side of the tube, are practically constant and entirely independent of the water velocity.

Resistance. The transfer of heat produced by the temperature head is opposed by a total resistance R which for analysis divides conveniently into the resistance R_v on the vapor or steam side of the surface, the resistance R_m of the metal walls of the surface, and the resistance R_w on the cooling water side of the surface. A simple equation expressing heat transfer in useful terms may be written as follows:

$$R = \frac{M}{H}$$

in which

H = number of heat units transferred per unit time

M = mean temperature difference

R = total resistance $= R_v + R_m + R_w$

Even with high steam pressures and with superheat, the total B.t.u. to be extracted by the condenser may safely be assumed as 1000, and it is convenient to adopt an arbitrary resistance unit such that

$$H = \frac{1000 \times M}{R} \text{ or } W = \frac{M}{R} \ldots\ldots\ldots [3]$$

in which

H = B.t.u. per sq. ft. per hour

M = mean temperature difference in deg. fahr.

R = resistance per sq. ft. of surface

W = pounds steam condensed per sq. ft. per hour.

The symbol U will be used when M is unity, so that U = B.t.u. per sq. ft. per hour per deg. mean temperature difference. This resistance R may also be expressed in terms of equivalent conductivity by the equation

Presented at the Spring Meeting of the Society, June 1915. Complete paper may be obtained without discussion; price 10 cents to members; 20 cents to non-members.

$$R = \frac{1000 \times L}{C \times 4290}$$

in which

L = thickness of substance in inches
C = conductivity in c.g.s. units.

The paper here considers the deduction of the resistances R_m, R_v and R_w and how they are influenced by design and by factors of operation, such as coatings of oil, air and scale, upon the condenser surfaces.

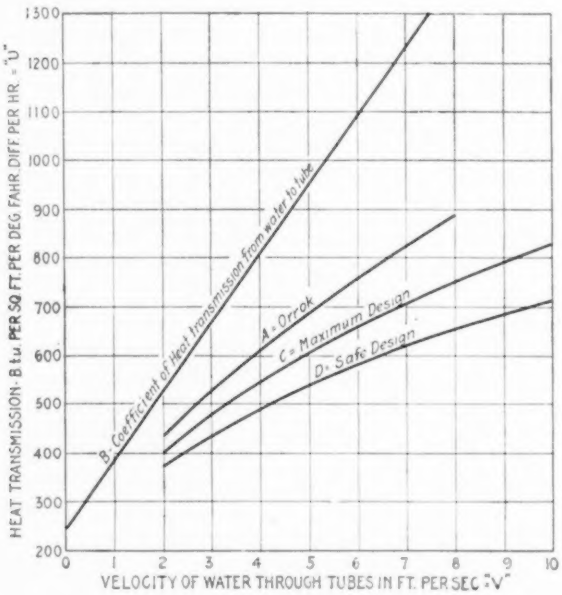


FIG. 1 HEAT TRANSMISSION—VELOCITY CURVES

The writer believes that the results of the tests by Orrok[1] (Fig. 1. Curve A) provide the most reliable data available on heat transfer through condenser tubes. In Fig. 2 (curve A) are plotted total resistances R obtained by applying the values from Orrok's curve in Fig. 1 to equation [3], in which M is taken as unity. For convenience, these resistances are plotted against reciprocal velocity instead of against velocity.

The paper shows that for ideal conditions $R_v = 0.333$ and that for a No. 18 gage brass tube $R_m = 0.044$, making $R_v + R_m = 0.333 + 0.044 = 0.377$, and it is reasonable to assume that Orrok's tests approach these conditions sufficiently closely so that a reasonable value to accept for $R_v + R_m$ for his tests is 0.4. On this assumption curve B, Fig. 2, is plotted showing the relation of R_w to the reciprocal velocity.

A curve, Fig. 1 (B), plotted from the values on curve (B), Fig. 2, represents the relation of heat transfer from the surface of a condenser tube to velocity of the water in contact with that surface. From this curve U_w varies directly with V according to the equation

$$U_w = 245 + 141\ V.$$

This variation of resistance, inversely with velocity, is due to the fact that the particles of water in contact with the surface at any instant form a non-conductor which prevents the flow of heat from particles in the body of the water to the surface of the tube. The transfer of heat is really by convection, and the more rapid the removal of the heated particles and their replacement by cooler ones, the greater the heat transfer. With the same velocity this transfer of particles is much more rapid in a small tube than a large one, where, so to speak, a cold core of water exists. This indicates the desirability of small tubes and experience dictates $\frac{3}{4}$ in. to $\frac{7}{8}$ in. inside diameter as a maximum.

For apparent reasons of economical construction most condensers consist of a cylindrical shell containing closely-spaced round tubes. The water may pass through the tubes and the steam around them, or vice versa. While the steam circulates automatically as a result of condensation, the water moves only sluggishly due to slight change of gravity with change of temperature. The arrangement, therefore, of passing the water through the tubes, is invariably employed, thus making it possible to give the water a rapid positive movement.

Among metals commercially available for use in condenser tubes, copper has the highest conductivity and when properly alloyed, is less subject to corrosion than most others, thus permitting the use of thinner surfaces. Hence practically all condenser tubes are copper or high percentage copper alloy.

The size of tube is a determining factor in the thickness, larger tubes requiring greater thickness for mechanical strength, and from this viewpoint also small tubes are desirable.

The arrangement of heating surfaces for easy cleaning and the construction of water channel covers independent of pipe connections is important, although frequently neglected.

To prevent the formation of a coating of oil which has an effect more serious than a coating of scale, a fairly high steam velocity must be maintained over the tubes, and corners which become stagnant places must be eliminated.

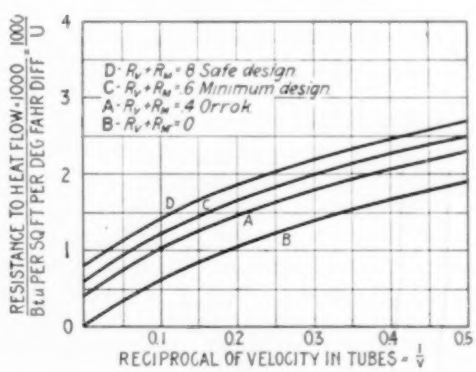


FIG. 2 RESISTANCE—RECIPROCAL VELOCITY CURVES

The paper here considers typical designs of condensers, pointing out their advantages and defects.

An exhaust opening of liberal size with a dome extending the length of the shell, Figs. 11 and 14, will cause the steam to be distributed to the ends of the tubes and prevent stagnant corners such as represented by the shaded portions in Figs. 3, 4 and 5.

Baffle plates for directing the steam to remote parts of the condenser introduce resistance to steam flow and should be avoided, except for the small plate directly in front of the exhaust inlet to protect the tubes from entrained water in the exhaust.

[1] Transmission of Heat in Surface Condensation, Geo. A. Orrok, Trans. Am. Soc. M. E., Vol. 32, page 1139.

The steam passing over the tubes condenses and diminishes in volume as it progresses, and hence in ordinary condensers the steam flow velocity rapidly decreases and becomes practically nil in the portion away from the inlet, permitting air to stagnate. This steam flow velocity may be maintained by constructing a gradually reducing steamway, a triangle with steam entering over one entire side, Fig. 6, being theoretically correct, or by gradually reducing the pitch of the tubes or by making lanes or passages to various parts of the steam space by omitting tubes, Figs. 11 and 14. Any one of these methods properly applied should be effective and result in good steam distribution at uniform velocities, prevent the stagnation of air at any point, and minimize the frictional drop.

Fig. 10 shows a commercial form of condenser which, however, has a shell of a shape that is somewhat inconvenient to construct. Fig. 9 shows similar taper passages embodied in a round shell, but the large heavy baffle plates which occupy the available tube space are objectionable. Fig. 7 shows this feature also, but the shape of the shell and the resistance to steam flow make it an unpractical construction. The design in Fig. 8 likewise has too many baffles which increase the weight and obstruct the steam flow. The design in Fig. 14 approaches that of the others in principle, but the shape of the water passages is objectionable; when a condenser is incorporated in the base of a turbine, these lanes should start from opposite the buckets as nearly as possible.

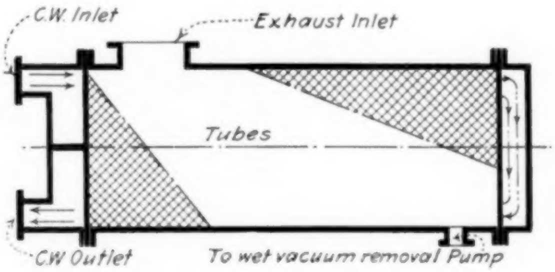


FIG. 3 CONDENSER ILLUSTRATING INCORRECT PARALLEL FLOW, INCORRECT WATER CONNECTIONS, AND NARROW WATER CHANNELS

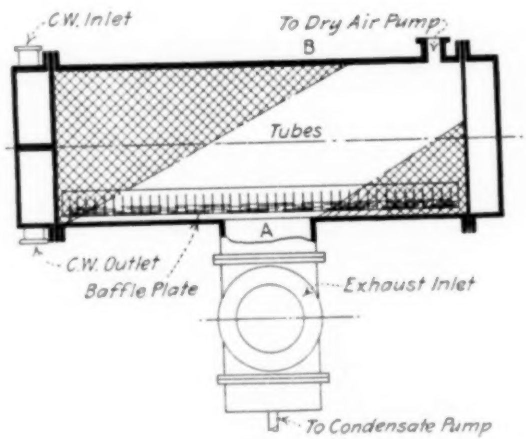


FIG. 4 CONDENSER SHOWING EFFECT OF EXCESSIVE BAFFLING, AND IMPROPERLY LOCATED AIR CONNECTIONS

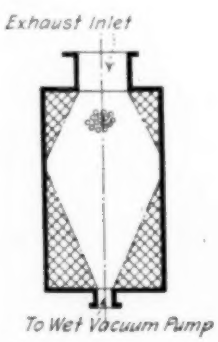


FIG. 5 HIGH RECTANGULAR CONDENSER

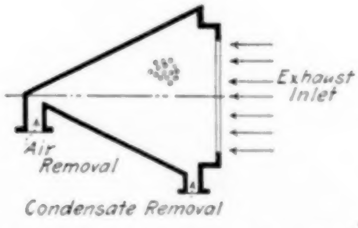


FIG. 6 THEORETICALLY-CORRECT CONDENSER SHAPE

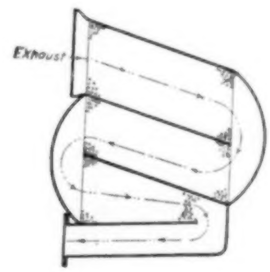


FIG. 7 TAPER PASSAGE CONDENSER, ILLUSTRATING RESTRICTED STEAMWAY AND UNCOMMERCIAL SHAPED SHELL

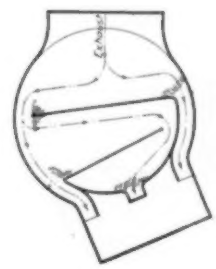


FIG. 8 TAPER PASSAGE CONDENSER, ILLUSTRATING RESTRICTED STEAMWAY

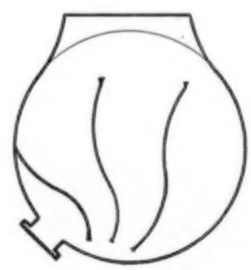


FIG. 9 ROUND SHELL CONDENSER, BAFFLED TO HAVE THREE TAPER PASSAGES

FIG. 10 MODERN ENGLISH TAPER PASSAGE CONDENSER

If a liberal pitch be employed for the tubes, and ample lanes be provided, the frictional drop, even through a large condenser, need not exceed 0.4 in. and less in smaller ones. Figs. 11, 13 and 14 show proper distribution, but Figs. 4, 7, 8, and 12, having long steamways and closely pitched tubes, may have frictional drops as great as 2 in.

It is important that a sufficient number of air removal connections be located at points where air accumulates (Fig. 11).

The quantity of air allowed to enter a condenser should at all times be minimized and the importance of tight joints and pipe connections should be impressed upon operators. As only a very small quantity can enter with the feed water, it is evident that proper operating attention to the tightness of condenser shell, low-pressure stages of the turbine, piping and valves, will reduce the air in the condenser to a very low figure. If a large quantity of air were present in a condenser, it could be detected by vacuum and temperature readings taken at the same part of the steam space, the temperature indicated being that of the vapor, and the pressure that of the sum of the pressures of the vapor and of the air.

In order to determine the completeness of the distribution of the steam to all parts of the steam space, the writer has computed the coefficient of heat transmission U for each pass for two large condensers and has found this coefficient for the first pass only about 10 per cent. less than for the second, indicating that with proper steam distribution and effective air removal the value of U will be about the same for all parts of the surface. If, however, steam distribution is poor and the clearing away from the surfaces and the removal of the air unsatisfactory, the value of U for the first pass may be only 50 per cent. of that in the second. In a like manner, if the tubes away from the center are not doing their proportion of work, this will be indicated by the temperature readings taken on the water flowing from them.

The resistance on the water side of the condenser could be eliminated if very high water velocities through exceedingly small tubes could be used. This, however, would cause a rapid increase of frictional resistance and consequent cost of pumping, erosion of the tubes if the water contained sand, and an undesirable number of passes or a very long condenser. For these reasons a velocity flow is ordinarily limited to about 4 to 6 ft. per second. Experience shows 1 in. outside diameter to be the lower limiting size of tubes and this allowable only in very large condensers having a high circulating water ratio. Frictional loss may be minimized by using long tubes and fewer passes, reducing water passage and tube entrance loss.

Even distribution of water through all tubes is important and narrow channels causing high velocities, Figs. 3 and 4, or inlets directing water onto the tubes, Fig. 3, must be avoided, since uneven distribution is sure to result, those tubes not in the stream line receiving little water and being therefore largely ineffective.

Curve C, Fig. 1, is arrived at by accepting a coefficient of heat transmission U, of say 550, for a water velocity of 4 ft. per sec. This coefficient is about the best obtainable in practice and there are considerable data available for this water velocity. By comparing this with the valve on curve B, Fig. 1, the value of R_v+R_m is determined as say 0.6, which is used in plotting the points on curve C, Fig. 2. Perhaps in most cases a value of 0.8 for R_v+R_m, giving curve D, would be safer to use for design. If we accept 4 as a desirable water velocity we obtain from curve D, Fig. 2, $R = 2$, corresponding to an allowable value for U of say 500 B.t.u.

There follows in the paper a consideration of condenser design with reference to desirable temperature conditions and methods of removal from the condenser for each of the four fluids.

Steam must be maintained at the lowest practicable pressure, and hence the temperature must approach closely that of the circulating water discharge. There must be a difference, however, in order to produce heat flow; this should be kept within 10 deg. fahr.

Air must be removed from the condenser by a mechanical pump, the energy required for operation being directly proportional to the volume of air moved. This volume

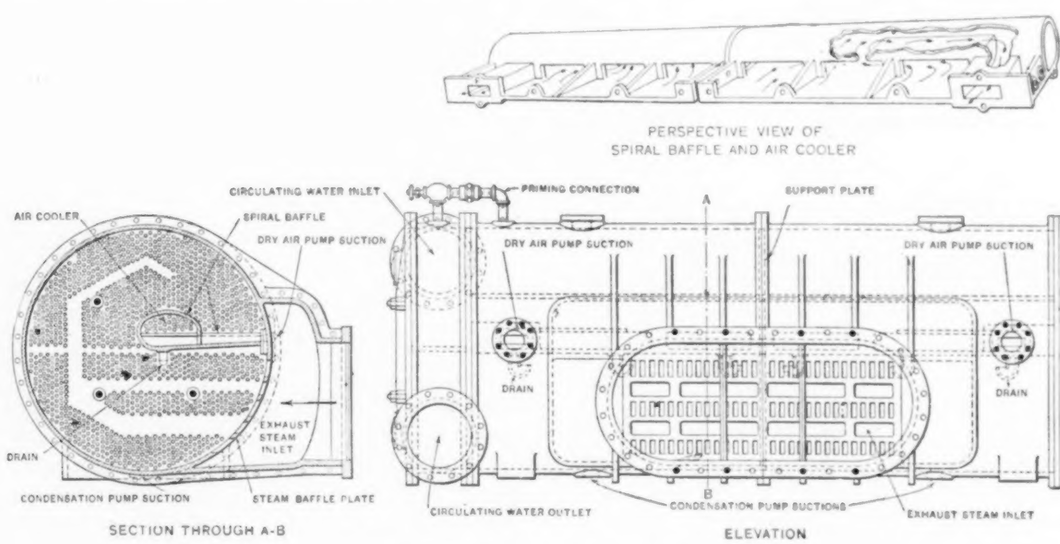


Fig. 11 Well-Designed Cylindrical Condenser

should be minimized by causing the air finally to pass over the coldest tubes.

The curves, Fig. 15, show the enormous effect, upon the volume of air mixed with saturated water vapor, of the partial pressure of the steam as indicated by the temperature. Thus, with a vacuum of 28 in. (2 in. absolute) corresponding to a steam temperature of 101 deg. fahr., 1 lb. of air, for a temperature of the mixture of 95 deg. fahr. corresponding to a partial steam pressure of 1.6 in. will have a volume of say 1200 cu. ft.; whereas if the partial pressure of the steam is reduced to 1 in. absolute, bringing the temperature of the mixture to 80 deg. fahr., this volume will be only 400 cu. ft. These figures indicate the importance of embodying in the condenser design an air cooler, especially in condensers with high vacuum.

Actual tests have proven that for ordinary wet vacuum pumps to handle the mixture of air, vapor, and water and maintain even moderately high vacuums it is necessary to cool the condensate 10 to 15 deg. below that due to the vacuum, which of course requires more circulating water and wastes more heat from the system. Another serious objection to the wet vacuum system is that compressing an emulsion of air and water is a most effective method of mixing the air with the condensate to return to boilers. Centrifugal air pumps having no clearance space, do not loose efficiency at high vacuums, and are rapidly coming into use, but the reciprocating type still has the advantage of requiring much less power for operation.

Condensate should be removed at a high temperature. Especially in large condensers, a number of condensate removal connections should be provided on the shell to insure free and quick flow to the removal pump, generally a centrifugal which, unlike a plunger pump, will handle varying quantities without speed changes, and which if properly vented never becomes vapor-bound.

Circulating water, to reach minimum quantity, must have an exit temperature closely approaching the steam temperature. The great effect of a comparatively small variation in this temperature may be appreciated by considering the maintenance of a 29 in. vacuum (79 deg. fahr.) with circulating water at 60 deg. fahr., the quantity required being twice as much if heated to within 14 deg. of the steam temperature, than if heated to within 9 deg., and the energy required to pump the circulating water being 8 times as much.

The optimum amount for this minimum temperature difference is always a compromise between condenser cost and pump and pumping cost, but with well designed apparatus should not exceed 10 deg. fahr. With poor designs, especially those having parallel flow, this difference is sure to be 15 to 20 deg. fahr. For service with circulating water obtained from cooling towers or other expensive source it might be warrantable to have this difference as low as 5 deg. fahr.

Regarding general structural features, proper provision for accommodation of expansion strains is usually accomplished by securing tubes into the tube sheets with packings and ferrules; a more modern method is to expand the tube into one head and pack at one end only, thus eliminating one half the leak possibilities. The proper supporting of tubes to prevent sagging and cracking is important and supporting plates drilled true with the tube sheet should be located not more than 8 ft. apart. Shells should be made of cast iron, and not of steel, which is corroded by the gases contained in the steam, and water channels and covers should be separate castings so that tube ends may be readily exposed for cleaning without breaking pipe connections.

The connections between and relative location of condensers and auxiliaries are important factors in condenser efficiency, but in most cases are beyond the control of the manufacturer and consequently are neglected and are a common source of condenser trouble. The exhaust pipe, condensate piping and air pump piping should all be amply large, although the last is ordinarily much larger than necessary.

The surface condenser, like most other apparatus, is subject to irrational, meaningless, and misleading ratings, the most objectionable being square feet per engine horse power, on account of the wide variation in the amount of steam required per engine horse power, say 9 to 25 lb. per hour. The more common rating is pounds steam condensed per

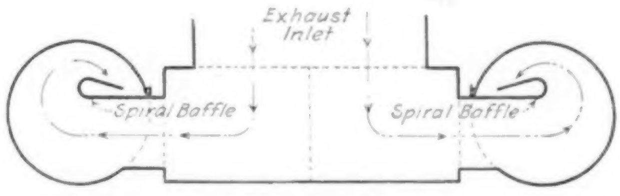


Fig. 12 Base and Double Wing Condenser, Illustrating Excessively Long Steamway

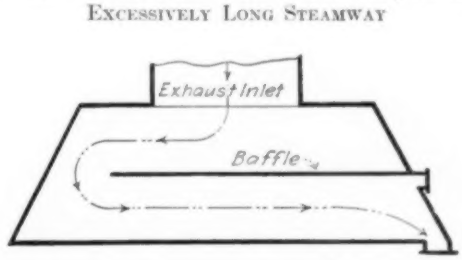


Fig. 13 Base Condenser with Taper Passage

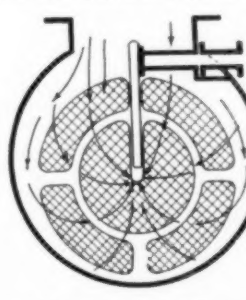


Fig. 14 Condenser Giving Taper Passage Effect without Baffles

square foot, common marine practice being to allow 1 sq. ft. per 10 lb. of steam and to hope for a vacuum somewhere between 23 in. and 26 in.; this is little better as it does not consider even cooling water temperature which may range from say 40 to 80 deg. fahr. A comprehensive rating must include the following:

(*a*) Quantity of steam condensed.
(*b*) Vacuum obtainable (corrected to 30 in. barometer).
(*c*) Temperature of available cooling water.
(*d*) Cooling water exit temperature.
(*e*) Condition of air at point of removal.
(*f*) Friction head on cooling water.
(*g*) Temperature of condensate at point of removal.

The first four items express the heat transmitting efficiency

and can for purposes of comparison be reduced to B.t.u per sq. ft. per deg. difference per hour.

Since a higher vacuum at the air pump than at the exhaust inlet is of no value, the mean temperature difference used for comparing results on condensers should be computed on the assumption that the steam temperature throughout the condenser is that due to the vacuum at the exhaust inlet and equation [2], the values for which can be determined from the chart, Fig. 15, should be used.

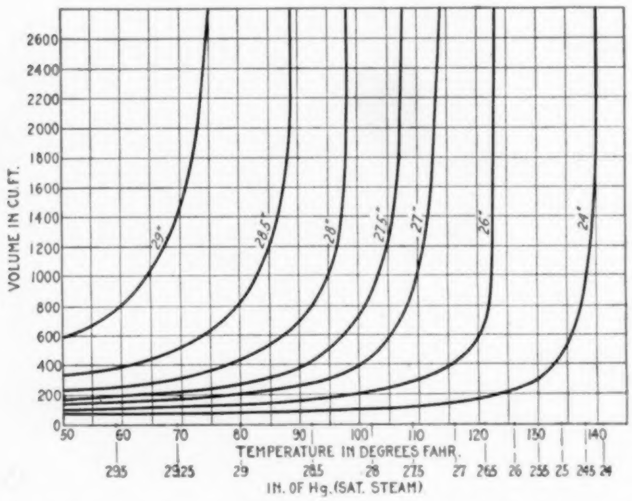


FIG. 15 CURVES SHOWING THE VOLUME PER POUND OF AIR MIXED WITH SATURATED WATER VAPOR, FOR VARIOUS TEMPERATURES AND PRESSURES OF THE MIXTURE

Fig. 16 is a diagram for the rapid determination of mean temperature difference values. Probably the most reliable formula for determining these is that of Grashof which when the temperature of one of the mediums is constant, reduces to

$$D = \frac{T_2 - T_1}{\log_e \dfrac{T_s - T_1}{T_s - T_2}}$$

where D equals the mean temperature difference, T_1 the lowest temperature of the fluid, T_2 the highest temperature of the fluid, T_s the temperature of the gas. The result will not be changed if any constant be deducted from all of the T's in the equation. By making this constant T the equation is simplified to one of three variables, which are plotted on the diagram, Fig. 16. To increase the accuracy or range of the diagram two scales are given; for temperatures between 200 deg. and 1000 deg. use the 100 scale. Five curves showing pressure-heat-temperature relations of steam are produced on the same set for convenient reference.

The complete equation for the condenser is

$$S = \frac{W \times Q}{M \times U} \text{ or } U = \frac{W \times Q}{M \times S}$$

in which

U = B.t.u. per sq. ft. per deg. fahr. difference per hour.
= coefficient of heat transmission.

M = Mean temperature difference in deg. fahr.

W = Pounds steam condensed per hour.

S = Square feet of cooling surface.

Q = Total heat removed by circulating water per pound steam condensed (usually taken as 1000 in all cases for simplicity).

Thus for example, assuming results as follows from two condensers, we can say that A is 50 per cent. more efficient than B.

	A	B
Square feet surface	2000	5500
Pounds steam condensed per hour	18500	57200
Vacuum	28½ in. (1½ in. abs.)	27
Temperature entering cooling water	65	60
Temperature exit cooling water	80	100
Mean temperature difference per equation [1]	18.3	30.9
B.t.u. per sq. ft. per deg. difference per hour	505	337

Items 3 to 6 determine the mechanical energy required by air condensate and circulating pumps. Item 7 indicates the heat efficiency, being a measure of the heat returned to the system in the condensate.

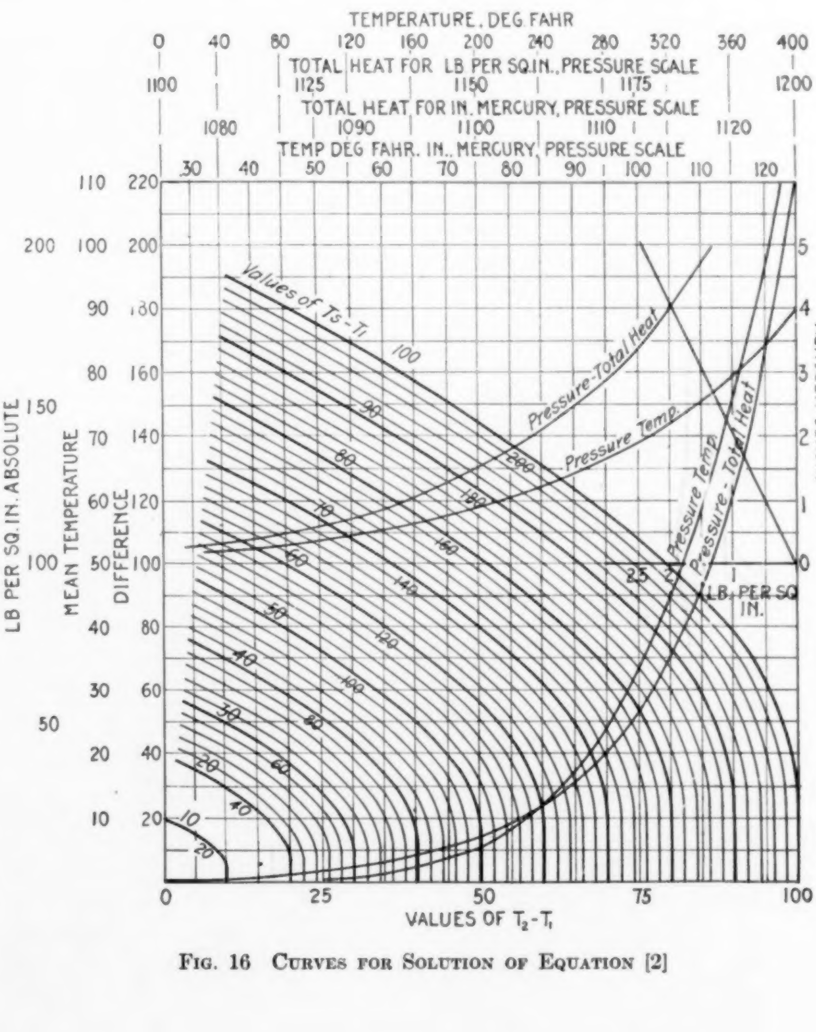


FIG. 16 CURVES FOR SOLUTION OF EQUATION [2]

DISCUSSION

P. E. Reynolds (written). A few years back it appeared to be the main idea of the designer to crowd as much cooling surface as possible into the least space, regardless of accessibility of the surface to the steam, or the friction loss entailed in bringing the steam to the surface.

There is no doubt that large exhaust openings, combined with steam distributing domes of ample dimensions and steam lanes or passages through the tubes, are some of the main features of efficient surface condensers designed to maintain high vacua.

Regarding the variations of heat transfer with water velocity, although Mr. Braun may be theoretically correct in stating that Mr. Orrok's exponential formula is fundamentally wrong, since the resistance to heat transfer of the tube itself and that on the steam side of the tube are constant, yet it seems that since these resistances are constant it is a useless complication for all practical conditions of condenser designs to take them into consideration.

Regarding parallel flow and counter-current condensers, I agree with Mr. Braun that the latter give the best results; however, Mr. Braun's proof of the fact by means of the general formula

$$M = \frac{D_1 - D_2}{\log_e \frac{D_1}{D_2}}$$

for the logarithmic mean temperature difference I do not consider correct. It is my understanding that in the mathematics involved in the derivation of this formula, the assumption is made that the heat absorbed by the cooler fluid results in a corresponding decrease in temperature of the hotter fluid. As these conditions do not prevail in a steam condenser, since the steam temperature is not decreased by the abstraction of heat at constant pressure, I would not consider that this formula could be correctly applied.

The formula:

$$M = \frac{TW_2 - TW_1}{\log_e \frac{TS - TW_1}{TS - TW_2}}$$

based on the assumption that the steam temperature $T\ S$ is constant throughout the condenser, is the only one that can be correctly used. However, it appears that too much weight should not be attached to the mean temperature as given by this formula, since the assumptions on which its mathematics is based are not fulfilled in actual surface condensers, and if a true mean temperature difference between the cooling water and steam is desired, it is probable that the arithmetical mean is as nearly correct as any.

H. Wade Hibbard mentioned that in the author's reference to the exhaust pipe between the engine and condenser he would suggest adding that in some installations it is desirable to use a steam separator to remove the water from the exhaust steam before it goes to the condenser.

The Author. Referring to the remarks of Professor Hibbard, who suggests that it may be desirable to have a steam separator between the prime mover and the condenser, I will assume that he thinks it advisable to remove the water from the exhaust steam so as to reduce the coating of condensate which will adhere to the condenser tubes. This has been tried many times, and very elaborately by one or two manufacturers, that is, by the installing of drain plates, which might be called separators, in the condenser; and it has been invariably found that these will offer resistance to the flow of steam, besides complicating and increasing the cost of the design, which more than offset any possible value that they might have in increasing the heat transfer by reason of decreasing the resistance on the steam side of the tube, and I feel sure that this is now an established fact.

Replying to Mr. Reynolds' remarks, I must point out some obvious fallacies.

His statement that the resistance R_v on the steam side of the tube, and the resistance R_m of the tube are, in condensers, nearly constant, does not agree with facts.

Actually, R_v varies greatly with varying amounts of air present, as is plainly apparent when one considers the marked effect upon vacuum produced by even the most minute of air leaks. Furthermore, repeated tests on two-pass condensers, from which the performances of each half the condenser has been computed separately, have invariably shown that the coefficient of heat transfer is less in that half which contains the air outlets.

R_m; which properly includes the resistance of *any solids adhering to the tube*, increases greatly, as we all well know, when the condenser becomes foul with scale or oil, and the value to be given it should depend upon the quality of the circulating water, the presence or absence of oil in the exhaust and the continuity of service required.

Mr. Reynolds' limitation of the logarithmic mean temperature difference formula is also incorrect. The only assumption involved in the mathematical derivation is the proportionality of heat transmitted to the first power of the temperature difference. This proportionality is not absolutely true in a commercial condenser, due to the presence of air, but it is certainly more desirable to start with rational and the theoretically correct formula, making allowances in practical design for known influencing factors, than to revert to rule of thumb methods and accept formulæ such as the arithmetical mean for temperature difference which we know to be fundamentally wrong. To fulfill Mr. Reynolds' conditions for the correctness of formula [1] it is only necessary to consider the steam as a fluid having an infinitely large specific heat.

THE RELATION BETWEEN PRODUCTION AND COSTS

BY H. L. GANTT, NEW YORK

Member of the Society

Mr. Gantt's paper at the Spring Meeting drew out a large amount of discussion, which is here reported nearly in full. The paper contends that, whereas it has been common practice to make the products of a factory running at a portion of its capacity bear the whole expense of the factory, the only expense logically chargeable to a product is that needed for its production when the factory is running at its full or normal capacity. The expense of any portion of a plant not needed in production is a business expense to be deducted from profits, or entered as a loss if the profits will not cover it. The determination of the expense required for normal operation is primarily an engineering problem, instead of an accounting problem, and the cost accountant of the future must himself be an engineer.

MANUFACTURERS in general recognize the vital importance of a knowledge of the cost of their product, yet but few of them have a cost system on which they are willing to rely under all conditions.

While it is possible to get quite accurately the amount of material and labor used directly in the production of an article, and several systems have been devised which accomplish this result, there does not yet seem to have been devised any system of distributing that portion of the expense known variously as indirect expense, burden or overhead, in such a manner as to make us have any real confidence that it has been done properly.

There are in common use several methods of distributing this expense. One is to distribute the total indirect expense, including interest, taxes, insurance, etc., according to the direct labor. Another is to distribute a portion of this expense according to direct labor, and a portion according to machine hours. Other methods distribute a certain amount of this expense on the material used, etc. Most of these methods contemplate the distribution of *all* of the indirect expense of the manufacturing plant, however much it may be, on the output produced, no matter how small it is.

If the factory is running at its full, or normal, capacity, this item of indirect expense per unit of product is usually small. If the factory is running at only a fraction of its capacity, say one-half, and turning out only one-half of its normal product, there is but little change in the total amount of this indirect expense, all of which must now be distributed over half as much product as previously, each unit of product thereby being obliged to bear approximately twice as much expense as previously.

When times are good, and there is plenty of business, this method of accounting indicates that our costs are low; but when times become bad and business is slack, it indicates high costs due to the increased proportion of burden each unit has to bear. During good times, when there is a demand for all the product we can make, it is usually sold at a high price and the element of cost is not such an important factor. When business is dull, however, we cannot get such a high price for our product, and the question of how low a price we can afford to sell the product at is of vital importance. Our cost systems, as generally operated at present, show under such conditions that our costs are high and, if business is very bad, they usually show us a cost far greater than the amount we can get for the goods. In other words, our present systems of cost accounting go to pieces when they are most needed. This being the case, many of us have felt for a long time that there was something radically wrong with the present theories on the subject.

As an illustration, I may cite a case which recently came to my attention. A man found that his cost on a certain article was 30 cents. When he found that he could buy it for 26 cents, he gave orders to stop manufacturing and to buy it, saying he did not understand how his competitor could sell at that price. He seemed to realize that there was a flaw somewhere, but he could not locate it. I then asked him what his expense consisted of. His reply was labor 10 cents, material 8 cents, and overhead 12 cents. My next question was: Are you running your factory at full capacity? I got the reply that he was running it at less than half its capacity, possibly at one-third. The next question was: What would be the overhead on this article if your factory were running full? The reply was that it would be about 5 cents; hence the cost would be only 23 cents.

The possibility that his competitor was running his factory full suggested itself at once as an explanation.

The next question that suggested itself was how the 12 cents overhead, which was charged to this article, would be paid if the article was bought. The obvious answer was that it would have to be distributed over the product still being made, and would thereby increase its cost. In such a case it would probably be found that some other article was costing more than it could be bought for; and, if the same policy were pursued, the second article should be bought, which would cause the remaining product to bear a still higher expense rate.

If this policy were carried to its logical conclusion, the manufacturer would be buying everything before long, and be obliged to give up manufacturing entirely.

The illustration which I have cited is not an isolated case, but is representative of the problems before a large class of manufacturers, who believe that *all of the expense, however large, must be carried by the output produced, however small.*

This theory of expense distribution is quite widespread, and clearly indicates a policy, which in dull times would, if followed logically, put many of our manufacturers out of business. In 1897 the plant of which I was superintendent was put out of business by just this kind of logic. It never started up again.

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Fortunately for the country, American people as a whole will finally discard theories which conflict with common sense; and, when their cost figures indicate an absurd conclusion, most of them will repudiate the figures. A cost system, however, which fails us when we need it most, is of but little value and it is imperative for us to devise a theory of costs that will not fail us.

Most of the cost systems in use, and the theories on which they are based, have been devised by accountants for the benefit of financiers, whose aim has been to criticize the factory and to make it responsible for all the shortcomings of the business. In this they have succeeded admirably, largely because *the methods used are not so devised as to enable the superintendent to present his side of the case.*

Our theory of cost keeping is that *one of its prime functions is to enable the superintendent to know whether, or not, he is doing the work he is responsible for as economically as possible,* which function is ignored in the majority of the cost systems now in general use. Many accountants, who make an attempt to show it, are so long in getting their figures in shape that they are practically worthless for the purpose intended, the possibility of using them having passed.

In order to get a correct view of the subject we must look at the matter from a different and broader standpoint. The following illustration seems to put the subject in its true light:

Let us suppose that a manufacturer owns three identical plants, of an economical operating size, manufacturing the same article,—one located in Albany, one in Buffalo and one in Chicago,—and that they are all running at their normal capacity and managed equally well. The amount of indirect expense per unit of product would be substantially the same in each of these factories, as would be the total cost. Now suppose that business suddenly falls off to one-third of its previous amount and that the manufacturer shuts down the plants in Albany and Buffalo, and continues to run the one in Chicago exactly as it has been run before. The product from the Chicago plant would have the same cost that it previously had, but the expense of carrying two idle factories might be so great as to take all the profits out of the business; in other words, the profit made from the Chicago plant might be offset entirely by the loss made by the Albany and Buffalo plants.

If these plants, instead of being in different cities, were located in the same city, a similar condition might also exist in which the expense of the two idle plants would be such a drain on the business that they would offset the profit made in the going plant.

Instead of considering these three factories to be in different parts of one city, they might be considered as being within the same yard, which would not change the conditions. Finally, we might consider that the walls between these factories were taken down and that the three factories were turned into one plant, the output of which had been reduced to one-third of its normal volume. Arguing as before it would be proper to charge to this product only one-third of the indirect expense charged when the factory was running full.

If the above argument is correct, we may state the following general principle: THE INDIRECT EXPENSE CHARGEABLE TO THE OUTPUT OF A FACTORY BEARS THE SAME RATIO TO THE INDIRECT EXPENSE NECESSARY TO RUN THE FACTORY AT NORMAL CAPACITY, AS THE OUTPUT IN QUESTION BEARS TO THE NORMAL OUTPUT OF THE FACTORY.

This theory of expense distribution, which was forced upon us by the abrupt change in conditions brought on by the war, explains many things which were inexplicable under the older theory, and gives the manufacturer uniform costs as long as the methods of manufacture do not change.

Under this method of distributing expense there will be a certain amount of undistributed expense remaining whenever the factory runs below its normal capacity. A careful consideration of this item will show that it is not chargeable to the product made, but is a business expense incurred on account of our maintaining a certain portion of the factory idle, and chargeable to profit and loss. Many manufacturers have made money in a small plant, then built a large plant and lost money for years afterwards, without quite understanding how it happened. This method of figuring gives a clear explanation of that fact and warns us to do *everything possible to increase the efficiency of the plant we have, rather than to increase its size.*

This theory seems to give a satisfactory answer to all the questions of cost that I have been able to apply it to, and during the past few months I have laid it before a great many capable business men and accountants. Some admitted that this viewpoint would produce a very radical change in their business policy, and are already preparing to carry out the new policy.

It explains clearly why some of our large combinations of manufacturing plants have not been as successful as was anticipated, and why the small, but newer plant, is able to compete successfully and make money, while the combinations are only just holding their own.

The idea so prevalent a few years ago, that in the industrial world money is the most powerful factor, and that if we only had enough money, nothing else would matter very much, is beginning to lose its force, for it is becoming clear that *the size of a business is not so important as the policy by which it is directed.* If we base our policy on the idea that the cost of an article can only legitimately include the expense necessarily incurred either directly or indirectly in producing it, we shall find that our costs are much lower than we thought, and that we can do many things which under the old method of figuring appeared suicidal.

The view of costs so largely held, namely, that *the product of a factory, however small, must bear the total expense, however large,* is responsible for much of the confusion about costs and hence leads to unsound business policies.

If we accept the view that the article produced shall bear only that portion of the indirect expense needed to produce it, our costs will not only become lower, but relatively far more constant, for the most variable factor in the cost of an article under the usual system of accounting has been the "overhead," which has varied almost inversely as the amount of the product. This item becomes substantially constant if the "overhead" is figured on the normal capacity of the plant.

Of course a method of accounting does not diminish the expense, but it may show us where the expense properly belongs, and give us a more correct understanding of our business.

In our illustration of the three factories, the cost in the Chicago factory remained constant, but the expense of supporting the Buffalo and Albany factories in idleness was a charge against the business, and properly chargeable to profit and loss.

If we had loaded this expense on the product of the Chicago factory, the cost of the product would probably have been so great as to have prevented our selling it, and the total loss would have been greater still.

When the factories are distinctly separate, few people make such a mistake, but where a single factory is three times as large as is needed for the output, the error is frequently made, with results that are just as misleading.

As a matter of fact it seems that the attempt to make a product bear the expense of plant not needed for its production is one of the most serious defects in our industrial system to-day, and farther reaching than the differences between employers and employees.

The problem that faces us is then first to find just what plant, or part of a plant, is needed to produce a given output, and to determine the "overhead" expense on operating that plant or portion of a plant. This is primarily the work of the manufacturer, or engineer, and only secondarily that of the accountant, who must, as far as costs are concerned, be the servant of the superintendent.

In the past, in almost all cost systems the amount of "overhead" to be charged to the product, when it did not include *all* the "overhead," was more or less a matter of judgment. According to the theory now presented, it is not a matter of judgment, but can be determined with an accuracy depending upon the knowledge the manufacturer has of the business.

Following this line of thought it should be possible for a manufacturer to calculate just what plant and equipment he ought to have, and what the staff of officers and workmen should be to turn out a given profit.

If this can be correctly done, the exact cost of a product can be predicted. Such a problem cannot be solved by a cost accountant of the usual type, but is primarily a problem for an engineer, whose knowledge of materials and processes is essential for its solution.

Having made an attempt to solve a problem of this type, one of the most important functions we need a cost system to perform, is to keep the superintendent continually advised as to how nearly he is realizing the ideal set, and to point out where the shortcomings are.

Many of us are accustomed to this viewpoint when we are treating individual operations singly, but few have as yet made an attempt to consider that this idea might be applied to a plant as a whole, except when the processes of manufacture are simple and the products few in number. When, however, the processes become numerous or complicated, the necessity for such a check becomes more urgent, and the cost keeper who performs this function becomes an integral part of the manufacturing system, and acts for the superintendent, as an inspector, who keeps him advised at all times of the quality of his own work.

This conception of the duties of a cost keeper does not at all interfere with his supplying the financier with the information he needs, but insures that information shall be correct, for the cost keeper is continually making a comparison for the benefit of the superintendent, of what has been done with what should have been done. Costs are valuable only as comparisons, and comparisons are of little value unless we have a standard, which it is the function of the engineer to set.

Lack of reliable cost methods has, in the past, been responsible for much of the uncertainty so prevalent in our industrial policies; but with a definite and reliable cost method, which enables us to differentiate between what is lost in manufacturing and what is lost in business, it will usually become easy to define clearly the proper business policy.

DISCUSSION

In presenting his paper at the meeting the author introduced it with the following remarks:

I was moved to present this paper not because the ideas were absolutely new, but because they are of such great importance to manufacturers, and are apparently so little understood by many of them.

Since publishing this paper I have had my attention called to the work of numerous accountants, and especially manufacturers, who, within the last few years, have discarded tradition, and made excellent progress toward a rational system of expense distribution. Some have apparently solved the problem completely. Nevertheless it is a fact that the generally accepted theory of only a few years ago, was that the product of a shop must bear the total expense of owning and operating that shop. It is also a fact that this theory is still misguiding many manufacturers. In addition, the expense of selling was often added as a part of the cost of the article.

The first step taken by students of this problem was to separate the cost of manufacturing from that of selling. According to this division, the expense of manufacturing stops when the article is delivered to the shipping department or placed in the finished stock room. All expenses incurred from this time on belong to the sales department and are deductions from profits.

This separation took one variable and confusing element out of the manufacturing cost; but with a widely varying product and a relative fixed "burden" or "overhead" charge, the manufactuirng cost was still subject to fluctuations over which the superintendent had no control, and hence not only gave no measure of the efficiency with which the shop was run, but was no guide at all to the salesman; and was actually misleading when business was dull.

The next step in the evolution of a rational cost system was to establish a fixed "overhead" based on past experience. This had the great advantage of making costs comparable, and of giving the salesman a definite limit by which to be governed.

It had the disadvantage that if the output was at a less rate than the usual previous rate, there was left unabsorbed a portion of this "overhead;" and vice versa, if the product was greater than at the previous average rate more "overhead" was accounted for than was actually incurred. Of the various methods adopted to take care of this residual "overhead," the two that are best known are, first by charging it to a fund that is eventually charged back on the cost of the product, and second by charging it directly to business as a profit or loss. The second method seems the most logical of the two, and for those who are guided only by what has been done in the past, seems to be entirely satisfactory. Indeed for him who is an accountant only, and not familiar with

manufacturing methods, it is apparently the only possible solution.

To the engineer, however, who is not so much concerned with *what has been done* as with *what should be done,* it is not at all satisfactory.

If a plant has been built that is larger than is needed to supply the available market, the business error of building the excess portion of that plant should not be charged as a manufacturing cost, but directly to the business as a loss. For instance, if we should build two identical plants where only one was needed, the expense of owning and maintaining one of them in idleness could not be charged to the goods manufactured in the other, but would have to be deducted from the profits of the business.

In the same way the expense of any portion of a plant not needed in production should not be charged to the articles produced, but is a business expense and must be deducted from profits, or entered as a loss, if the profits will not cover it. *In other words, the only expense logically chargeable to a product is that needed for its production when the factory is running at its full or normal capacity,* which may be quite different from that used in its production in the past.

Inasmuch as the determination of this fact is primarily an engineering or manufacturnig problem, and not primarily an accounting problem, it becomes evident that cost methods must be based on engineering knowledge, and the cost accountant of the future must himself be an engineer or manufacturer, or be guided by one.

Granting this, it is safe to predict the early dawning of the day longed for by Uncle John Sweet, when *the man who knows what to do and how to do it* shall gradually supplant *the man who knows what was done and who did it.*

D. B. Rushmore. Speaking entirely from an individual standpoint, I would say that all of my experience points to the fact that free industrial competition in general means nothing but final bankruptcy. This is because of certain elements of human nature which, for a great variety of reasons, allow business to be taken by someone below cost.

In figuring the cost of any product the largest and most indeterminate item is usually the overhead expense, and the proper use of this overhead after it is once obtained is of course the difficult part of the problem. The manufacture and production of power and commodities is usually subject to considerable fluctuations, and in the extreme case of a small power house for a widely fluctuating load, in which the power may vary from zero to a maximum over irregular intervals, the instantaneous cost of power will vary enormously. These fluctuations may be momentary, hourly or even annually, and the proper distribution of the overhead in order to determine the average cost is necessarily a problem requiring judgment.

The year has usually been taken as the unit of time. The question is, can this period be enlarged so as to include an average of several of the past years, and can these figures be used in an attempted prophecy of the future. It would certainly seem as if this were a feasible and sensible point of view.

Forrest E. Cardullo. I think the idea advocated in the paper is correct, but there are two points to which I would call attention: One is that the loss incurred and charged to profit and loss must be made up in the selling price. The other one is the question as to whether it is better to charge that loss annually against the product, or to capitalize it and get rid of it once and for all.

W. N. Polakov. The question is, whether the cost at which a product has been manufactured in the past is the cost at which this product shall be and can be manufactured. If the overhead is not properly differentiated from the cost of production; and if the cost of production is not known,—not as it was in the past, but as it ought to be,—we shall not be in a sound position.

To quote an example, there is an electric plant which carried \$200,000 overhead a year. The records show that the plant generated current at between 0.72 and 0.68 cent per kw., depending on the load factor.

If with an annual output of 60,000,000 kw-hr. (or about half capacity), the overhead charges were distributed per kw-hr., it would be $^1/_3$ cent; if the output were 80,000,000, the overhead would be ¼ cent and if there were a full output of 120,000,000, allowing a margin for peaks and breakdowns, the overhead would be 0.166 cent.

Consider at the same time that the capacity of the plant may not have been sufficient for the increased business and that a public utility company was willing to sell any amount of current for 0.83 cent per kw-hr. One would immediately, in accordance with the old method, go to the old records and get the lowest figure, 0.68 cent, for which current had been manufactured, and then add the minimum overhead of 0.166 cent, giving 0.85 cent instead of the 0.83 cent which the public service corporation offered. On this basis one would seem to be warranted in buying the current, at least for the present, because of the saving of 0.02 cent on every kw-hr. When new records are compiled, it would be found that the cost of production of the plant in question had risen to 0.91 cent because the output was reduced and the overhead was 0.25 instead of 0.166. We finally come to the point where we think there is no use of carrying our plant any longer, so it is shut down and all the power purchased outside at 0.83 cent.

If this were done it would mean that we would get the power at 0.83 cent, plus the overhead on the dead plant of \$200,000. In this case the cost per kw-hr. would be 0.996 cent, and we would then remember that while the plant was in operation current had been manufactured for 0.85 cent. Where would be the expected saving? It apparently was there,—it was on the books, but it appears to be lost. Where has it gone? One fallacy of such calculations is that we use the past records instead of the exact scientifically established standard of what the cost ought to be. In fact, in this case it ought to be only 0.4, as I know from actual experience that the cost was brought down in this plant from 0.72 to 0.44, which, added to the overhead even in accordance with the old method, would be only 0.6, consequently the expected saving of some \$25,000 on the plan of buying power would be turned into a loss for the company of over a quarter of a million dollars.

W. W. Bird. This paper is of special interest to me as it indicates in a way the evolution of the mechanical engineer. Twenty or thirty years ago we came to the meetings of this Society and we heard Thurston talk about the steam engine indicator. The mechanical engineer of those days made boiler and engine tests. Ten years ago we heard Taylor tell

about the stop watch and routing cards for workmen. The mechanical engineer of that period not only went into the power house of an industrial plant, but also into the shop. The engineering thought as expressed by the planning department was carried out in the shop just the same as the ideas as expressed by the blue prints from the drafting room were followed.

Now Gantt comes along and tells us that it is not good engineering to put all of the shop burden on productive labor all of the time. In other words, the mechanical engineer of today is applying the general principle of cause and effect in the office of our industrial plants the same as he has in the other departments.

At the Worcester Polytechnic Institute, we are working along these lines and our students have laboratory work in the office of our commercial shops just the same as they do in the steam and other laboratories.

Good engineering is needed in the accounting department and I am very glad that the author has presented this paper for our consideration. We ought to tackle this problem of

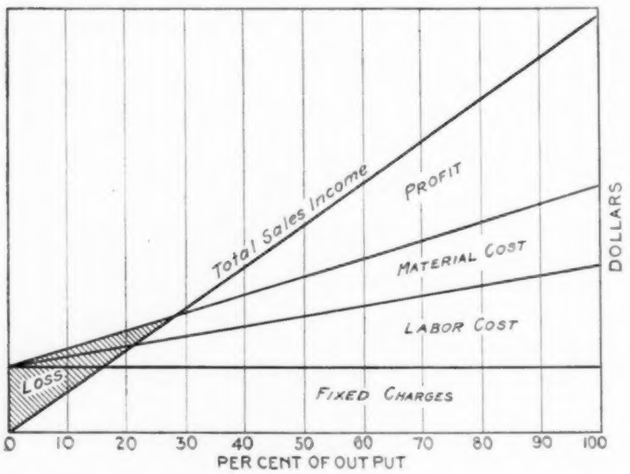

FIG. 1 DIAGRAM SHOWING RELATION OF FIXED CHARGES, PRODUCTION COST AND INCOME

shop burden the same as we would one in power transmission. Let productive labor carry that part of the burden for which it is responsible and can regulate, and let the men higher up do the same.

The responsibility of our manufacturing plants should not be divided. Starting from the top, responsibility should be delegated and definitely placed and then if a plant cannot be made a success, let the self executing laws of nature do their work and put the plant out of existence.

JAMES A. WHITE showed a diagram, Fig. 1, which he had found useful in determining the effect of fixed charges. Assuming that it is known what the fixed charges are, a line is drawn to represent them as indicated. Above are added lines to represent labor and material costs, which vary with the output. A fourth line represents sales income, which varies directly as the amount of business done, and starts at the zero point of the diagram. The point where the sales income line crosses the total cost line indicates where it is advisable to shut down the factory; the shaded space at the left indicating loss, and the upper space at the right, profit. This diagram is difficult to apply to a factory, but it is easy of application to such a concern as a gas company, whose fixed charges can be accurately determined.

CONTRIBUTED DISCUSSION

CHARLES PIEZ. No matter to what degree of refinement a cost keeping system may be carried, costs are, at best, but fairly accurate approximations, and to be even that must represent averages over long periods. If the costs are to be used as the basis of selling quotations, they should be based on normal and not on exceptional conditions.

Too many manufacturers still sell at what they assume to be the market price, in the hope that ingenuity and rigid economy will let them out at a profit. But permanency in business will never be the lot of the manufacturer who permits the buyer to name the price and who does not fortify his position by a thorough knowledge of costs.

With the wide fluctuations to which manufacturing is unfortunately subjected, it is essential that a fairly accurate determination be made of what normal capacity, normal expense and therefore normal costs are; very few factories run uniformly at 100 per cent capacity; a great many vary in the course of a business cycle from 50 per cent capacity in times like the present, to 150 per cent capacity in boom times. Not only is there wide variation in total output, but departments frequently show great variations independent of general business conditions.

As a rule, a manufacturing enterprise whose business shows considerable fluctuation must have a capacity slightly in excess of the normal or average requirements if prompt service to the customer is necessary.

In our own business we have assumed normal output to be the output of each department secured by its full complement of men working 2500 hours per year which represents 90 per cent of the possible working hours per annum on a 54-hour week basis.

The average factory expenses are distributed on a pay roll representing this degree of activity and our average or standard departmental and general expense factors are based on the output which this degree of activity represents. Costs are based on the average factors, and are therefore fairly uniform and wholly independent of the fluctuations of business.

At the end of each month the standard or average factors are compared with the actual factors for each department and the total of all expenses is compared with the total obtained by distributing the standard rates. In times of depression the standard rates fail to distribute the total expenses and the debit balance goes to reduce the profits. When the business is running considerably above the assumed normal the standard factors produce a credit balance which goes to increase the profits.

The sheets showing the comparison between actual and standard expense rates, which the cost department submit to the management each month, keep the management informed and enable it to correct the standard rates when changed conditions render corrections advisable. By following the method of distributing expenses through carefully ascertained standard factors, we secure in a ready and practical way the results which the author advocates.

In this connection it might be well to point out the opportunity for a valuable service which the Society might render not only to its members, but to the manufacturing community

at large. The Society has the honor of having recommended several mechanical standards, which have had universal adoption. Would it not be wholly within its province to give the subject of expense distribution in mechanical plants some attention, and make recommendations for the standardization of such distribution?

There can be no real comparison of costs unless there is uniformity in cost accounting; neither will violent fluctuations in prices in times of depression cease until uniform and standardized systems of expense distribution take the determinations of costs out of the realm of conjecture and place it on a firm foundation of ascertained facts.

Frank H. Neely. This paper does much to clear up the uncertainty with which most manufacturers consider indirect expense and its application to costs. Further, it shows in clear relief the urgent need of the engineer in laying out and deciding upon the business issues of manufacturing.

In times such as we are just passing through, the idea of making money has to give way to the idea of the preservation of a working organization and of taking care of the workers who in good times past have helped make the profit, and who, if the author's idea is followed out, will have a great deal of work that would otherwise have gone to factories not so apparently loaded down with indirect expense.

About three years ago, in standardizing the processes in a factory making a complete line of candies and crackers, I found it necessary to develop my cost records very much along the line of the author's paper. This business is seasonal, and in the three fall months the volume is practically double what it is in any other similar period in the year.

This, of course, made the costs appear high in the first part of the year and extremely low in the busy season, which forced the standardization of costs on the lines described in the paper for the individual product; and each department, as the year progresses, shows its profit or loss, at the same time absorbing its just pro rata of indirect expense, regardless of the volume manufactured.

Sterling H. Bunnell. The reason why cost systems are generally of so little use to the manufacturer is that they are planned for no other purpose than to meet the needs of the accountant in balancing his books. The fact that cost keepers are accountants and not manufacturers is the only explanation of the belief so prevalent that the cost of the product of a given month is equal to the total expenditure of the month.

The fact is, that the cost of to-day's product is the result of the whole past existence and future purpose of the factory organization. Experience is expensive before it becomes a direct source of profit; equipment, working force, financial resources and goodwill all enter into the cost, not only of the factory product of to-day, but also of the product of future days and years. The cost of the day's product, therefore, includes more than the chance portion of the total cost of operating the plant that happens to get into the day's accounts.

Cost records are expensive, and, therefore, have no reason for existence if not practically useful. They should show the works management that the cost of product is within its proper standards. For this purpose, the items of material and direct labor are sufficient, and the burden figure of secondary importance. But the cost figures should also show the sales department the minimum selling prices which will cover the total of operating cost. Material, direct labor and factory burden furnish only part of the total which selling price must cover in order to insure continued profit.

The determination of this extra overhead necessary to maintain an average of profit is the great problem of factory accounting. The tools in continuous use must carry the expense of those which may be idle, and the busy years must earn the profit for the times of bad trade. The reservation of a surplus, to provide stability of dividends, is generally approved. In an unprofitable year, the unearned dividend may then be paid from the surplus. The use of an account for unearned burden, and offsetting this deficit by a proper increase in the general overhead rate, is exactly parallel. Every lost minute of operation causes a loss in earnings. If idle tools are necessary incidents of the business, the losses on them must be made up from the general income of the plant, or a deficit will result. This accords with the principle set forth by the author. The time lost in the factory operation must in the end be paid for by a mortgage on the busy hours; but there is no reason why the mortgage should be foreclosed immediately by writing off the whole cost of operation against the product of the lean month, when that would involve selling at an apparent loss.

It is indeed surprising that there are business men who do not seem to realize that high efficiency is more profitable than surplus capacity. As the charges on idle equipment must be carried by the equipment which runs, there should be just as little idle plant as possible. Fluctuations in demand are better cared for by increasing output with existing equipment, than by adding new tools which are likely to stand unused under average conditions. It is often easier to buy more machines than to find the causes of loss of output by the present ones. But, when the inevitable contraction comes, the management which has met demands by increasing the output of the existing plant instead of by adding equipment, is likely to be in position to continue dividends by drawing on an ample surplus.

Keppele Hall. The author's contention that overhead or indirect charges cannot be arbitrarily distributed over product without regard to conditions, and still have costs serve as a useful guide to the management or superintendent, is illustrated by the following example:

An electric light company in a small town was supplying current for lighting and a small amount of power. The business necessitated running the plant all day, although the day load was very light. An opportunity was offered to secure a very good day load by furnishing power to a street railway company, but the price at which the contract could be obtained was below the cost of production. This cost of production included the entire overhead expense prorated over the output. At first sight the proposition seemed undesirable; but on further investigation it appeared that, with the exception of a small amount of oil for lubrication and a negligible increase in depreciation owing to increased load, the only additional expenditure necessary to take on this business was the cost of the extra coal consumed and the removal of the extra ashes. No additional employees would be required in the power station or in the office. The contract was accepted and, in spite of the increased output, the price obtained was *below cost*. As a matter of fact the in-

come derived from this contract paid the company's entire coal bill and very handsomely increased the net profits. If this matter had been judged entirely on costs, it would have appeared a losing proposition, while as a matter of fact, it proved a dividend payer. Of course, this business could only be considered feasible as long as the demand for the higher priced lighting current did not encroach on the reserve capacity of the plant.

An objection that might be raised against the author's proposed solution of overhead expense distribution is that it does not hold the superintendent responsible for such items of the indirect expense as he has under his control during slack times. For example, suppose the normal output is 100 and necessary indirect expense is $100. If the output drops to $50 and the indirect expense to $80, the output would be charged with $50 and the remaining $30 would be thrown into a profit and loss or business account. How are we to know whether or not the superintendent is rightly responsible for a portion of that $30, which he might have saved? In such a case is it not advisable to divide the indirect expense, hold the product responsible for such portion of it as the superintendent can control, and relieve it of that portion over which he has no control?

It would appear that task work has a very important bearing on the subject of accurate costs. Where tasks have been scientifically set, and where the proper amount of material has been determined upon, the superintendent's chief responsibility is to see that, whatever the conditions of business, the work is done in the proper time and the proper amount of material is used. If this is strictly followed, any extra expense incurred on account of poor business conditions is not the superintendent's responsibility.

A good arrangement for proportioning indirect costs is to have a machine or work place rate fixed so as to cover all indirect expense under normal conditions. Each job is then charged with the direct labor and material and the machine or work place hours. The balance of the indirect expense, which is not absorbed by the machine and work place rates, is placed in an account known as an under-absorption account. This account increases in dull times and decreases in very busy times. The net result at the end of a given period shows the under or over-absorption of the indirect expense. The cost of the product is estimated from the sum of the three items (labor, material and machine or work place hours), and, except for variations in the efficiency with which the work is done, holds the costs practically constant. An account of this kind is very useful in equalizing costs over periods of slack production which are apt to occur in almost any business. It also serves to equalize unusual expenses which in some processes are incurred at certain periods of the year, such for example as with a product which requires a large amount of steam in cold weather and practically none in warm weather. This arrangement distributes this unusual expense over both periods and tends to equalize the cost.

A matter, which is not given the importance it deserves in management, is the fact that it is possible to regulate almost any business so there will be no great variation in output due to seasonal demands for the product or variations in the condition of business. Proper management should make an effort to control these conditions and has done so in a number of cases.

For example, a concern manufacturing automobiles has standardized its output so that it does not vary from one year's end to the other. This has been accomplished by offering special inducements to agents to dispose of the product during the dull season and also by manufacturing its product during this season, except some of the more expensive parts which can be put on in a comparatively short time, and holding this product until the seasonal demand arises.

CARL G. BARTH. The question Mr. Gantt endeavors to answer in his paper is only another form of the old question of how low we may take orders in dull times, and it does not seem to me that he has reached the bottom of it.

The true answer to the question may be made no matter what the policy of a concern regarding the distribution of its overhead expenses, so long as these are definitely known and properly analysized.

This is by means of what Mr. Taylor called dull time "limit costs," the making up of which is practised by all concerns which fully understand the true nature of manufacturing costs.

In very dull times it is unfortunately not so much a question of how much money we can make by taking orders, but how to manage so as to hold an organization together and to lose as little money as possible, for the fixed charges go on even if we take no orders at all and allow the organization to disband.

In making up a "limit cost," we therefore leave out all consideration of the fixed charges of a plant, and also such other overhead expenses as, without being absolutely fixed, become so for the time being, because we purpose not to disrupt our organization entirely.

The overhead expenses to be added to flat labor and material in making up a limit cost are, therefore, such only as will actually be incurred by virtue of undertaking the work under consideration.

If this limit cost is less than the market value of an article it will then be correct to manufacture the article ourselves rather than to buy it, or to offer it in the market for anything, however little, over and above this limit cost, for this margin will help carry the fixed charges.

Suppose the limit cost of the article in the case cited in the paper could have been shown to figure up to 20 cents only, this would have constituted a still stronger argument against the buying of the article at 26 cents, even if the full and true cost at the time of manufacture was 30 cents.

R. E. FLANDERS. In the firm with which I am connected the plan is followed of setting the overhead rate to agree with average business conditions over a long period, taking into account both good times and bad. An overhead account is carried, to which are charged all the items that go to make up the shop overhead expense; and in like manner to this account are credited all sums apportioned as overhead charges to work in process.

In busy times there will evidently be a deficit in this overhead account. In dull times, on the contrary, the continuance of the heavy expenses, coupled with the small volume of productive labor to which they may be applied, will produce a heavy unapportioned balance in the account. The plan is so to set the average overhead rate that the deficits and excess balances will about cancel each other. From time to time this overhead rate requires adjustment to meet

changed business conditions, both internal and external. These changes are, however, neither frequent nor violent.

This plan, without doubt, is used by many other concerns besides my own, all of which have doubtless been led to adopt it for substantially the same reasons. It is worth while, therefore, to compare this plan, which we may call the *average rate* plan, with that set forth by the author, which we may call, for simplicity, the *proportional rate* plan.

In the first place, the average rate, being practically unchanging, is the more easily applied.

The average rate has the same advantage as the proportional rate in the matter of avoiding sudden and violent fluctuation in the cost figures due to corresponding fluctuation in the output.

The average rate offers the most direct method of distributing what may be called the "cataclysmic" overhead expenses. In this category are included such items as taxes, etc., which impose a disastrous load on the period in which they fall, unless they are apportioned piecemeal over the full term to which they apply.

The main difference between the two plans is that with the average rate the burden of carrying idle equipment and organization through dull times is distributed into the cost of work in good times, while the proportional rate takes it out of the cost system entirely and charges it to profit and loss.

Now, I contend that there is good reason for absorbing this periodically recurring expense in costs, rather than in profit and loss. This charge has not the nature of an extraneous calamity, like an embezzlement or unwise investment. We are forced, unfortunately, to reckon with cycles of boom and depression as one of the conditions of doing business in this country. This condition is therefore a regular factor in the cost of production, and should be so treated.

This argument becomes all the stronger when it is remembered that cost figures have a two-fold use. Not only are they employed for comparison with previous costs, but they are used as well to determine whether articles can be profitably manufactured at a given selling price; in some cases, in fact, they are used for setting selling prices. There is nothing like having all unavoidable expenses firmly imbedded in the cost figures, instead of allowing them to rattle around loose in the ledger.

To sum up the matter, it may be said that the use of the average rate directly disagrees with what the author states as a fallacy, that *all of the expense, however large, must be carried by the output produced, however small.* In fact, it seems to me to be the prime merit of the average rate plan, when based on an overhead account, that no legitimate expense escapes from distribution to costs. The errors which the author sees in this principle are not inherent in the principle at all, but are caused by an illogical application of it. The *average rate* seems to me to answer all, or nearly all, of his objections.

The proper solution of problems such as outlined by Mr. Gantt, of a factory running below normal capacity, is independent of any particular method of applying overhead charges. You can increase its output without perceptibly increasing the overhead charges, and you may safely reckon the cost of the increased production as equal to labor plus material only. Forget about the overhead. Any margin between the cost and the price at which you can buy or sell may be considered as profit, in the sense that it will, by that much, help to carry your overhead and thus reduce your expenses. This is not a matter of accounting, but of common sense.

In his discussion of the effect of the size of a plant and of a business the author opens up a line of thought which leads to interesting conclusions as to the ideal size of plant. That size, for a concern manufacturing staple articles, would seem to be such as to be able to take care of some reasonable percentage over the minimum demand in dull times. A plant so proportioned, with reserve and credit good enough to run full and build a fair stock in dull times, could be operated with the minimum attainable overhead rate. It would therefore capture practically all of this dull time business, and get, as well, the maximum profit on its output in good times, if it were well managed otherwise. In fact, the greatest danger to such a business would be the ever-present temptation to expand—a temptation which, if yielded to, might entirely undermine the foundations of its prosperity.

D. C. Ferner. Mr. Gantt's interesting paper suggests hope for a branch of cost accounting that is still struggling for intelligent analysis and even a semblance of uniformity. I refer to a proper determination of the cost of operating motor trucks. Every alternate step in production, conversion and distribution of any product is that of transportation. Raw stock, stock in process, finished stock must be moved on to the ultimate consumer. At many points motor driven road trucks, shop trucks, crane trucks, tractors and trailers can be used to advantage, but comparatively few managers can see the necessity for making the change. Present methods are built around equipment very limited as to capacity and sales value, but strong in associations, sentiment and book valuation. Depending on how good a horse trader the stable boss may be, the manager figures he can use horses and hand trucks for several years to come. He hesitates to adopt machine equipment on account of its initial cost, and its cost of operation. He has never kept accurate costs of horse delivery and the very limited amount of machine costs that are available are based on conditions that do not fit his business. He finds too that each machine is loaded with a fixed portion of the yearly overhead charges of the installation, whether the particular machine has been in operation all or a portion of the time. In other words a fixed charge is made against each machine working or idle and at the end of the year the total fixed charges for the year have figured prominently in the "cost of operation per mile" or per ton.

Following the author's suggestions, if a motor truck is laid up for lack of work its fixed charges or overhead for that period should be charged against profit and loss, and it should be up to the manager to find outside work for his trucks.

Going still further, if a motor truck is laid up for repairs, the fixed charges for that period of time should be added to the cost of repairs, and should not appear as fixed charges against the actual cost of operation.

By a proper analysis of operating and maintenance costs, the manager can always find a guide for reducing the idle time and increasing the earning capacity of each individual machine and the installation as a whole.

C. Bertrand Thompson. One important purpose of factory cost accounting is to provide a basis of comparison of

the cost of production from one period to another. Obviously, for this comparison to be of any value, the items to be compared must be based on similar conditions; or if this is impossible, the varying factor should be isolated in such a way that its influence may be separately considered.

A normal manufacturing cost is that which is accurate when the plant is running at its normal capacity, and this should be made the basis for comparison. Therefore, if the plant is not running at its normal capacity, the factor of idle time must be kept account of separately if comparisons are to be of any value.

The conclusion from these considerations is that in periods of depression and subnormal operation, costs should be figured on the basis of the equipment actually used, and the cost of idle equipment should be determined and charged simply in the profit and loss account, to be taken care of in the selling price so far as competitive conditions permit.

Mr. Gantt notes that this method may affect the policy of the plant, but unfortunately does not offer a suggestion as to what the new policy should be. Merely charging the cost of unused plant and equipment to profit and loss does not really solve the problem, which is—How can this loss be made good? When it is a question of closing whole plants there is a possibility of selling them and thus at least cutting off a part of the loss; but when it is a question of part of a plant being unused it is practically impossible to end the loss by merely disposing of the superfluous part.

One suggestion offered is to take the possibility of subnormal operation into account in setting the normal selling price. This is good so far as competition permits and so far as only average deviations from normal operations are anticipated. It cannot, however, take care of long continued abnormal conditions such as we have been experiencing. Viewed broadly, the condition of subnormal operation in a plant is due to the sales organization rather than the producing organization, not overlooking the fact that the sales organization has a perfectly legitimate excuse for not keeping the plant busy up to its fullest capacity. In view of this fact, the producing organization should not be penalized for the lack of opportunity to produce.

The excess cost should not of course be charged to the sales department any more than to the producing department. Special emphasis nevertheless, should be laid on the fact that it rests on the sales organization to reduce or eliminate the loss.

Here is a field for a further application of scientific management. Thus far this type of organization has been limited almost exclusively to production, and there it is doing extraordinarily effective work. Its successful practitioners in this field ought not to be expected to undertake the considerably different problem of distribution. But there is a clear call for the application to the marketing problem of the same type of analysis, scientific research and accurate determination of laws and principles that has characterized the development of scientific management in production.

William Kent. Mr. Gantt's paper is an admirable presentation of the evils that result from the adoption of a system of costkeeping, usually advocated by accountants, in which all the indirect expense, burden, or overhead, in a given period of time, such as a month, is charged as part of the cost of the output of that period, even if the amount of that output, on account of depression of business or other cause is far below normal. The only excuse for such a system is an accountant's one, that it enables the cost ledger to be balanced each month.

Mr. Gantt's statement of the general principle or theory of the correct method of charging indirect expense against product is strictly sound and logical, but it is not a new theory or principle. I have been acquainted with it and have believed in it for many years, although I do not recall that I have seen it in print. I have often made a statement of the principle something like this: "The burden to be charged against any product is the average burden of a normal year for the same quantity of product. If the total cost of keeping a certain machine in a shop for a year, including cost of light, heat, power, repairs, depreciation, rent, etc., divided by the number of hours the machine may be expected to run in a normal year is say 20 cents per machine hour, then the charge for burden to be made against the product of that machine is fixed at 20 cents per hour for the time the machine runs in the following year, whether it runs the normal number of hours or not."

In this connection attention may be called to an example of incorrect reasoning which sometimes follows a strict adherence to distributing burden on the machine hour system. An owner of a machine shop who had a tabulated hourly burden charge for each machine, varying with the size of the machine, the cost of running it and the number of hours that the machine was expected to run in a year, noticed that a small piece was being turned in a very large lathe. He told the foreman that he should not use the lathe for that piece because the burden charge on it was too heavy, and it would make the piece cost too much. The foreman replied that all the other lathes were busy and that there was no heavy work on hand for the large tool, and he thought he would make the big lathe "do something for its keep." The foreman was right, and, moreover, the burden that should be assessed against that piece in making up its cost, if the cost was to be used as a basis for estimating on future orders for similar pieces, is not the machine hour rate of the big lathe, but only that of a small one, on which the work would ordinarily be done.

The Author. If I am to draw any conclusions from the discussion of this paper, it has had the effect which I hoped it would have, namely, to make clear that a cost accountant to be really useful to a manufacturing company must understand the manufacturing process.

There is one point, however, which does not seem to have been clearly grasped by some, and that is that what I propose as the real cost of an article is not what it apparently has cost in the past, but what it should cost if the proper manufacturing methods were used and the shop were run at full capacity. This might be called the *ideal cost*, and toward its attainment all efforts should be directed. Mr. Polakov's discussion illustrates this most clearly.

It was perhaps twenty years ago when the great necessity for a knowledge of costs began to be apparent, and manufacturers in general began to give the subject careful consideration. The demand for "cost accountants" soon became so great that almost any clerk who had had experience in a manufactuirng plant was able to get a job as cost accountant, much as, today, almost anybody who calls himself an "efficiency engineer," even though he may never have had any

engineering experience whatever, seems to be able to gain the confidence of some manufacturer.

Such cost accountants, with a few high-sounding theories and a little bookkeeping experience, but with absolutely no shop knowledge, have too often been able to gain the confidence of the financier, whose policy has been governed by the reports obtained from such sources. The result of such an epidemic of cost accounting has undoubtedly been seriously detrimental to our industries, and it is with a great deal of satisfaction that I see the best accountants of today absolutely repudiating false theories and, if not actually keeping pace with engineers on the subject, at least traveling the same road.

The class of people that advertised themselves as "cost accountants" when "costs" was the watchword, today follow the slogan of "efficiency." This is certainly a step in advance as far as their work is concerned, but before we sacrifice everything on the altar of "efficiency," let us ask whether efficiency is a *means* or an *end,* and get the answer.

It is our duty to ourselves and to society to do well, or efficiently, whatever we do but are we not in danger of losing sight of our object if we lay too much stress on the efficiency with which we strive for it?

It does not take much thought to convince us that *efficiency* is not an *end,* but a *means;* and that it may be beneficial or detrimental as the end is worthy, or unworthy.

To do efficiently something that should not be done at all, benefits nobody. Would it not be better to do something worth while, however inefficiently? Let us stop, therefore, in this wild cry for efficiency long enough to ask what its proper aim is.

If its object is to enable the few to accumulate wealth at the expense of the many, it is not worth while, for an industrial system that allows this will finally fail. If its aim is to enable one man to take unfair advantage of another in any manner it is not suitable to a democratic nation; and it is the country as a whole that must be considered, when we discuss such a broad question as this.

The greatest problem before our industrial world today is the establishment of harmonious coöperative relations between employer and employee. Efficiency is one of the most potent factors in the solution of this great problem, but it can be directed either for or against this solution.

Should we not know on which side it is to be used before we commit ourselves to it?

Before we support too strongly, then, this striving for efficiency, let us be sure that it is to be directly toward a worthy object. Efficiency alone will not cure our troubles, for misdirected efficiency *may be* just as detrimental in the future, as misdirected *cost accounting* has been in the past.

On the other hand, a combination of properly directed efficiency and proper cost methods are absolutely essential to the solution of our industrial problems; and the hopeful thing about the newer ideas of cost keeping is that they point the way of measuring not only the efficiency of the workmen, but that of the manager and of the financier.

Past methods have too often not only failed in this respect, but have frequently been so devised as to relieve the man at the top of the responsibility that was justly his, and to saddle it on the subordinate. The introduction of methods that will relieve this situation will be a long step in the solution of our industrial problems.

FOREIGN REVIEW AND REVIEW OF PROCEEDINGS OF ENGINEERING SOCIETIES

ENGINEERING SURVEY

There are still some people inclined to make a distinction between theory and practice. An article abstracted in the present issue brings a rather striking illustration of the fact that of late such a distinction is rapidly losing its sense. On the face of it, an investigation into the velocity of reaction in chemical processes belonging to what is known as physical chemistry, would appear to be "highly theoretical" and quite removed from "practice" and yet here we have a description of an entirely practicable and apparently valuable process for the production of hydrogen, based exclusively on the knowledge of facts derived from an investigation into the velocities of reaction at various temperatures as affecting the relative inertia of chemical processes.

THIS MONTH'S ARTICLES

The analysis and testing of explosion engine fuels are extensively discussed in an article in a German periodical.

Data of tests on air permeability of various building materials are reported, including such comparatively recent materials as chalky sandstone and perforated bricks.

The theory of resistance of rolling a hard body over a plastic surface is reported from an article in a Russian technical periodical, where also are given data from tests on the power consumed by wheels equipped with metal tires rolling over soft ground, of the power consumption in pure rolling of an American caterpillar tractor and the economy obtained in transporting heavy pieces of artillery by the use of the so-called Bonagente band.

An automatically operating refrigerating apparatus of Swiss design is described in considerable detail.

In the section on Steam Engineering is described a special system of replacing boiler tubes, which not only allows of the use of old tubes over and over again, but makes a joint between an old tube and the boiler actually stronger than one between the boiler and a new tube to which this method has not been applied. In the same section are discussed methods of calculation of safety valves with high lifts. The author shows that the so-called Cario formula for safety valves with high lift does not apply in the case of high efficiency boilers, and quotes tests showing that with valves dimensioned in accordance with that formula, the steam pressure may, under certain conditions, exceed the maximum permitted limit. A process of calculating de Laval nozzles by means of the PV diagram is reported from a German periodical.

From the Journal of the American Society of Naval Engineers is abstracted a paper on heat transmission and tube length in marine feed water heaters, by Leo Loeb. Particular attention is called to this paper both on account of the experimental data reported and very interesting theoretical considerations presented by the author.

Some fallacies in cement testing are discussed by W. Lawrence Gadd in the Transactions of the Concrete Institute. Among other things, the author calls attention to the fact that tests of fineness of cement are apt to give erratic results because the mesh of the sieve is but seldom uniform and also because, while the mesh is specified, the size of the sieve which may materially affect the results is, as a rule (in particular in the British Standard specifications), overlooked. The author likewise does not see that there is any use in the specific gravity test.

A paper by F. J. Schlink, on automatic scales, has been abstracted from an advance publication in the Scale Journal. It is of interest as giving a reliable classification of various types of automatic scales and describes the various fundamental principles of their construction.

The very important subject of the hardening of metals is discussed in abstract from the Transactions of the Faraday Society. While lack of space prevented the giving of more detailed abstract of the various papers presented to the Society on that subject, it is believed that interesting data will be found in the abstract of papers by Professor Ernst Cohen, of Utrecht, J. C. W. Humfrey (The Amorphous Phase in the Hardening of Steels) and Sir Robert Hadfield.

The question of the future developments in heating and ventilating is discussed by A. H. Barker, before the Society of Engineers. The author takes a rather novel view of some sides of that important branch of engineering, reports data of interesting tests and, among other things, explains certain phenomena which have been recognized for a long time but not fully understood; e.g., the unpleasant effect produced by radiator heat. The author distinguishes between temperature of air and radiant temperature, describes apparatus for measuring either of the two and attempts to throw light on some little understood phenomena by separating both the above referred to kinds of temperature.

From a bulletin of the University of Illinois are described experiments referring to the study of boiler losses.

FOREIGN REVIEW

Internal-Combustion Engineering

Analysis and Testing of Explosion Engine Fuels.

The article discusses the question of the utilization of gasoline, benzol, motor spirit and other fuels in explosion engines, with special regard to automobile motors. It is very complete, covers extensive references to German publications, both books and articles, and goes fully into the question of analysis and testing.

The author points out that hitherto the sale of gasoline, benzol, etc., was mainly based on confidence in the seller and that it is only quite recently that an attempt at establishing specifications has been made. The author believes that the pleasure vehicle will use, in the future as now, real gasoline, which he calls, in this connection, "luxury" gasoline; that the commercial vehicle might use mixtures of gasoline and benzol or heavier oil generally, and that stationary engines will use the cheapest and heaviest grades.

As mentioned above, the author discusses in detail the methods of testing motor fuels, under the following heads: *a* Determination of specific weight; *b* Color and external appearance; *c* Test by smell of the filter residue; *d* Length of evaporation on a watch glass; *e* Behavior with respect to litmus paper; *f* Color reaction with sulphuric acid; *g* Qualitative and quantitative determination of aromatic hydrocarbons and unsaturated combinations; *h* Benzol test by

means of isatin and sulphuric acid, (0.1 isatin and 30 grams sulphuric acid); *i* Benzol test by nitration with nitric and sulphuric acids; *j* Benzol test by means of "dragon ruby" (a special preparation made from pitch obtained from the blood of a Sumatra palm dragon); *k* Test for the determination of coal tar, lignite, benzine and sulphur compounds by means of silver nitrate; *l* Test for water by means of calcium chloride; *m* Fractional distillation; and, *n* Investigation of fuels by refraction.

The purpose of the article is to help in establishing a standard specification for fuels used for various purposes; the author gives samples of such specifications, viz., three specifications for gasoline (light automobile grade, middle weight commercial vehicle grade, and the still heavier grade for stationary engines) motor benzol and motor spirit. *Die Analyse und Wertbestimmung der Motoren-Benzine, -Benzole und des Motor-Spiritus des Handels*, Dr. Karl Dieterich, *Automobil-Rundschau*, vol. 16, no. 9/10, p. 65, May 1915, 32 pp., *peA*.

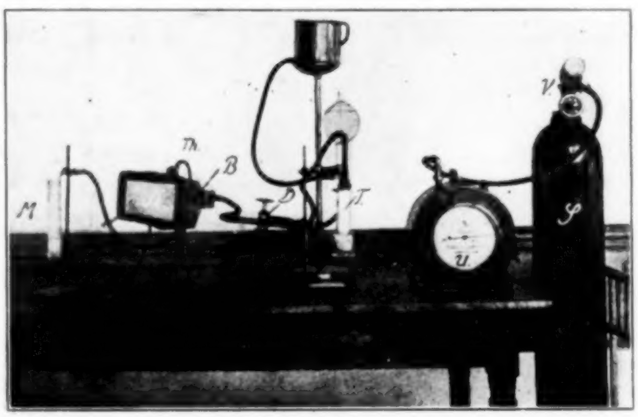

Fig. 1A Arrangement for Testing Air Permeability of Building Materials

Running Diesel Engines on Tar Oils.

By cutting off the supplies of Galician oils, the war forced the Austrian engineers to turn their attention to other sources of fuel for running Diesel engines. The most natural were various forms of tars and tar oils with which considerable experience has been gained elsewhere previous to the war. The present article discusses the character of these new fuels, their methods of use (with some practical advices), and design of Diesel engines for heavy oils. Some test data are given. (*Dieselmotoren mit Teerölbetrieb*, Hans Schmidt, *Elektrotechnik und Maschinenbau*, vol. 33, no. 23, p. 277, June 6, 1915, 6 pp., *p*).

Materials of Construction

Air Permeability of Building Materials.

This paper presents data on air permeability of various building materials.

Investigations on the same subject have been previously carried out by C. Lang (in 1877) and by W. Gosebruch (in 1897). The present investigation was carried out in the laboratory of technical physics of the Technical High School at Munich, and was prompted by the necessity of determining the air permeability of materials which have been brought out on the market in recent years, for example, chalky sandstones.

The permeability was determined by means of the experimental arrangement shown in Fig. 1A. The stone *St* was placed in a funnel shaped sheet iron container *B* and packed, air tight, on the sides with a mixture of plastilin and putty made of wax and colophonium. The stone, on one side, is exposed to atmospheric air and on the other side to a gage pressure of about 100 mm of water produced by an air supply from the steel flask *S* containing air under a pressure of 150 atmospheres and equipped with the reducing valve *V*, by means of which the air can be taken for any length of time at any pressure desired. From the valve, the air passes through an air meter *U* and a drying flask *T*, to the funnel *B*. The drying flask contains calcium chloride by means of which the moisture is, as far as possible, kept away from the stone *St*. Between *T* and *B* there is a three-way cock *D*, by means of which the air meter *U* may be calibrated without dismantling the experimental arrangement (the method of calibration of the meter is described in detail). Directly in front of the material investigated are located, through cock

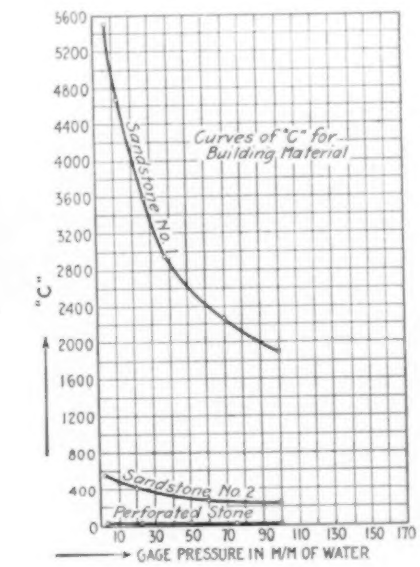

Fig. 1B Curves Showing Coefficient of Permeability for Building Materials

stoppers, a water manometer *M* and thermometer *Th*. The readings of these instruments enable one to reduce the volume of air flowing through to the normal conditions of 760 mm mercury pressure and 0 deg. cent. temperature.

The material investigated was of various thicknesses, on the average 60 mm. The part of the stone facing the outside atmosphere had often to be limited to 10 x 10 cm. because with a larger area of outflow the air velocities in the meter and drying flask were too high, which created undesirable disturbances, such as carrying over of particles of calcium chloride into the piping. The duration of test was, on the average, 30 min., and air temperature about 20 deg. cent.

Each test was, as a rule, repeated three times and the data reported represent an average of all the three tests. The Lang law was sometimes used in calculations; viz., that the volume of air flowing through is inversely proportional to the thickness of the material. The values obtained are shown in the second column of Table 1. From them is calculated

the coefficient of permeability c, under the assumption that the volume of air Q flowing in a unit of time through an area F of stone is inversely proportional to its thickness d, and directly proportional to the gage pressure p. Under this assumption the volume of air flowing through the stone is defined by the equation

$$Q = c\,p.\,F$$

and c indicates therefore the volume which will flow per hour through 1 sq. m. of stone surface, 1 m. thick, at a gage pressure of 1 mm. of water (Table 1, because of lack of space, is given in an abbreviated form). The "perforated stones" were bricks having four cylindrical perforations of 4 cm. in diameter, running parallel to their long edge, 12 cm. long. In addition to tests at the constant gage pressure of 100 mm, a series of tests were also made at variable pressures, data of which are given in the original article in

TABLE 1 DATA OF TESTS ON AIR PERMEABILITY OF BUILDING MATERIALS

Material	Q−1 per hr.	c (Average value)
Sandstone	5,680,000	
	3,715,500	
	3,136,500	997
Chalky sandstone	76,060	
	39,170	
	29,060	14.4
	4,890	
	4,760	
	2,670	1.23
Perforated brick	36,640	
	32,720	
	7,474	
	4,547	5.83
Hand made brick (hard burned)	7,540	2.26
Machine made brick	8,346	
	6,820	
	1,915	
	1,880	1.42

a table. From these data, the coefficient of air permeability c was calculated and is shown in the curves of Fig. B. As has already been noticed by Gosebruch, c is not constant but increases as the pressure decreases, this increase being materially greater with goods of porous material than with tougher materials. The decrease of air permeability with an increase of the pressure differences is to be e plained by the fact that the rapid growth of frictional resistance at greater pressure differences, and hence increased velocity of flow, produces a strong reduction of the motion of air through the material in the case of materials with very large pores. There is, in addition to that, the influence of flow produced by the phenomenon of expansion and turbulent motion in the hollows which affects still more the air permeability of the material at higher pressures. (*Die Luftdurchlässigkeit von Baumaterialien,* Hans Freiherr von Thielmann, *Gesundheits-Ingenieur,* vol. 38, no. 23, p. 265, June 5, 1915, 3pp., 3 figs. *e.*)

Mechanics

THEORY OF RESISTANCE TO ROLLING OF A HARD BODY OVER A PLASTIC SURFACE

The present investigation has been made in connection with the design of the first tractor constructed in Russia.

When the tractor was first built, it was found that losses due to pure rolling constituted 40 per cent of the useful output of the engine, which of course made the tractor very inefficient. Certain alterations of design reduced these losses to 25 per cent., which showed the importance of accurately understanding the phenomenon of rolling resistance. The present investigation has in view only rolling resistance of such bodies as wheels of wagons, tractors, and chains used on caterpillar tractors. In addition to that are investigated the driven wheels of modern heavy field artillery pieces, equipped with flat band shoes of the Bonagente type.

The general property of the surface of rolling of such bodies is that one can entirely neglect both the elastic and permanent deformation in their surfaces of rolling as compared with the deformation of the roadways of rolling (such as have been considered in the present case). These limitations exclude the use of rubber automobile tires and other elastic tires. Further, the investigation is limited to the case of rolling where the resistance to rolling is sufficiently large; that means types of ground, and such loads, which permit of neglecting the elastic deformation of the roadway as compared with its permanent deformation.

Finally, in order to derive general laws of rolling resistance, it is necessary to know the law of resistance of the ground to crushing under the conditions of crushing which occur in rolling. The author derives the following formula for expressing the specific resistance f in kg per sq. cm of the ground to crushing

$$f = f_o.y \quad \text{[1]}$$

where f_o (In kg per cu. cm) is the coefficient of specific resistance of the ground to crushing, i. e., the load in kg per 1 sq. cm of surface of ground, which causes permanent deformation of the ground to a depth of 1 cm. This formula shows that the specific resistance of the ground to crushing is proportional to the depth of the permanent deformation or crushing which corresponds to it.

As regards the resistance to rolling proper, *Appell* considers that pure resistance to rolling represents a couple opposing the rolling; the axis of this couple is parallel to the line of contact between the rolling body and ground, and may be located along the latter. The author considers only the case when the rolling body moves uniformly forward along a horizontal surface. The resistance to rolling R, he measures by the work of rolling L_k referred to a unit of length of path l travelled through by the body. In such a definition, the resistance to rolling is thought of as a certain imaginary force applied at all points of the rolling body, which has its axis of rotation traveling through paths identical with that of the entire body. The work of rolling in the general case is that work of the rolling body which is done by the surface forces acting between the surfaces of the rolling body and the ground (while the work of rolling necessarily includes that of sliding, the latter is here neglected). If the rolling body is assumed to be hard, no work is spent on the deformation of its surface since none is supposed to take place. In the case of rolling a hard body over plastic ground, the entire work of rolling represents the work of crushing of the ground, its slip and friction of the surface of rolling against the ground. The work of internal resistance, such as friction in the journals, and the work of gravity on inclines, are not included in the work of rolling. The essential feature in the dynamic method applied by the author to the determination of resistance to rolling is the

calculation of the work of deformation of the ground, the latter being determined from the conditions of equilibrium of the body, i. e., equilibrium of load applied to it, tractive effort and resistances of the ground.

From this, the author proceeds to the investigation of resistance to rolling on soft ground of the endless chain of a caterpillar (the tests were made on an American tractor made by the Holt Caterpillar Tractor Company). In the first part of the investigation it is assumed that the chain is smooth; that is, without protuberances which grip against the ground. The width of the chain is B cm and the length, L cm. The load Q kg is assumed to be distributed uniformly over all of the bearing surface, the specific pressure of this surface against the ground being represented by $q = \frac{Q}{BL}$. In that case, in the ground a deformation will occur to the depth y_o, at which the specific resistance of the ground f in kg per sq. cm will balance the specific resistance of the bearing surface $q = f$, wherein $f = f_o . y_o$.

It was found, by the way, that if the average value of f_o of specific resistance of the ground be known, the depth of crushing of ground by the caterpillar of the tractor can be found from the following expressions:

$$y_o = \frac{Q}{f_o\, B.L}\ ;\ f_o = \frac{Q}{y_o\, B.L}\ ;\ Q = f_o . y_o .\ B.L \ldots\ldots\ldots [2]$$

In order to calculate the work of compression of the ground to the depth y_o cm, the coefficient f_o is assumed to be the same as above, which means that the work of slip of ground and the work of gliding of the chain over the ground is neglected, which can be done because these losses are actually practically negligible. The specific resistance of the ground f, which is overcome over an elementary section of the ground dy, will cause an expenditure of work $f.dy$ and over the whole path y_o the compression of the ground $l_o = \int_o^y F\ .\ dy = \int_o^y F_o\ .\ y_o\ dy = F_o \frac{y_o^2}{2}$ which is (in kg per cm) the *specific work of deformation*, on the assumption that the specific pressures and depths of deformation are proportional to each other. Let the specific resistance of the chain to rolling be equal to R kg, and the tractor travel an arbitrary distance of s cm. The work done by the resistance R will then be Rs kg per cm and this work of rolling is the work of deformation of the ground. But if the tractor travel through a distance s cm, the deformation made by the chain over this distance will represent a groove of area Bs and depth y_o cm. The specific work of deformation to depth y_o is $F_o \frac{y_o^2}{2}$ and hence the total work of deformation over an area Bs will be

$$Bs\ F_o \frac{y_o^2}{2} = Rs, \text{ hence}$$

$$R = \frac{F_o y_o^2}{2}\ .\ B \ldots\ldots\ldots\ldots\ldots [3]$$

From this the author proceeds to the investigation of resistance to rolling of wheels of heavy artillery pieces equipped with flat band shoes of the Bonagente type. He goes through the calculation very carefully, and, among other things, compares the resistance to rolling of a Bonagente band with resistance to rolling of a cylindrical wheel of the same diameter and width of rim. He determines the formula and finds that while, with the Bonagente band, the expenditure of energy for the motion of the heavier gun is 3.14 h.p., the same gun, when moved on wide cylindrical wheels, will require 19.3 effective h.p., which shows that the introduction of flat movable supporting elements on the surface of rolling axles of all kinds of conveyances decreases the resistance to rolling of this surface many times. Among other things, he shows that in a chain (caterpillar type) rolling along a certain roadway, the coefficient of resistance to rolling increases in proportion to the load, while the resistance to rolling of the chain increases in proportion to the square of the load; hence, it is very inadvisable to overload the chain. With the same specific load per unit of over-all supporting surface of the chain, the resistance to rolling and the coefficient of the resistance to rolling of the body is greater the wider the chain and smaller the narrower the chain, but a long narrow chain is more advantageous than a wide, short one. In this connection, the author points out an interesting similarity between the caterpillar chain on one hand and a ski or skate on the other hand. Experience has shown that the latter two must be long and narrow in order to reduce the resistance to minimum. In general, whenever the friction of gliding goes together with crushing, destruction, or wearing of the roadway, it will depend not only on specific pressure of the body against the roadway, but also on the width of the body normal to the direction of motion. (*Teoriya soprotivlenya katanya tverdava tyela po plasticheskamoo pooti*, B. B. Schultz, *Proceedings of the Imperial Russian Technical Society* (in Russian), vol. 49, no. 3, p. 81, March 1915, article not finished. *etA*).

Refrigeration

Automatically Operating Refrigerating Apparatus "Autofrigor"

The article describes refrigerating devices and installations of the Swiss Federal Exposition in Bern 1914. The part abstracted here refers to an automatic cooling apparatus for household use, called "Autofrigor," built by Esher Wyss & Co., Zurich, Switzerland.

The apparatus consists essentially of a reciprocating compressor built in, together with the condenser, in the casing K and driven by a vertical shaft from the electric motor M. Below the casing is located a ribbed evaporator R, the whole having therefore the shape of a vertical cylinder and taking up very little room. Methyl chloride is used as a cooling medium. Many of the details of design are of interest. The cylinder of the compressor z, has an oscillating motion. It is supported by transversal pins and presses upward by a spring against the slide face provided with suction slots forming the path by which the gas penetrates from the suction chamber a into the double acting cylinder, and then, by the pressure valve v, into the lower pressure space b. The ascending pipe r_1 conducts the gas to the upper pressure chamber c and pipe r_2 to the condenser e. The latter has an annular shape and is equipped with ribs running screw-wise, this being done in order to force the cooling medium to describe a longer path. The liquid which condenses because of the inclined position of the ribs, sticks in the neighborhood of the cold outer wall. The condenser is surrounded by a jacket m, through which cooling water flows in countercurrent. This external annular chamber is also provided with ribs in order to increase the water velocity. When it is necessary to clean the cooling surfaces, the jacket m can be easily taken off without opening the engine itself.

The cooling liquid condensing in the condenser collects at the bottom of the chamber *e* and then flows through the reducing nozzle *d*, where the pressure and temperature are reduced to the lowest stage possible in the evaporator. Instead of the regulating valve necessary with the ordinary ice machine, here an expansion nozzle is used. The evaporator *R*, provided with ribs, takes up heat from outside and is protected by a sheet iron jacket in order to prevent the cooling liquid near the walls from being affected by the heat of the evaporator.

The construction of the driving motor *M* is also peculiar.

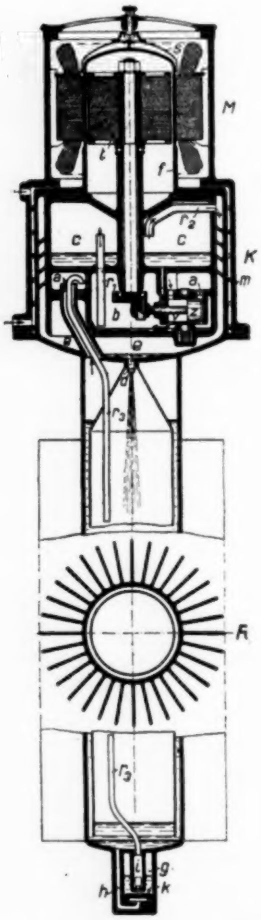

Fig. 2 Automatic Refrigerating Apparatus "Autofrigor"

Its rotor *t* is enclosed by a rigidly fixed armature and separated from it by a steel liner *f*. In order to have the eddy loss low, this liner is made of a special steel. In this way the pressure chambers *b* and *c* are separated from the outside atmosphere, air tight, without the use of any stuffing box. *f* has therefore to stand the gas pressure at the upper temperature stage which, in accordance with the temperature of the cooling water, may vary from 1.6 to 6 atmospheres. Tests made with this liner have, however, shown that permanent deformation occurs only at pressures from 80 to 100 atmospheres.

The lubrication of all movable parts has been provided for with particular care. Glycerine, which is used for this purpose, is placed in the upper pressure chamber *c*, and from there reaches all the lubricated parts of the compressor,—the piston, crank and shaft ends. It then collects in the lower pressure chamber *b*, and is carried over again into the chamber *c* by the cooling medium, through the pipe r_1. The pipes r_1 and r_2 open therefore into the chamber *c* in such a manner that the lubricant would never, not even with the apparatus in a horizontal position, overflow and run from the apparatus. A small part of the glycerine is atomized and carried off by the cooling medium to the condenser chamber *e* and by nozzle *d* penetrates into the evaporator *R* where it collects at the bottom. When the machine is stopped, the pressure between *c*, *e* and *R* rapidly equalizes through the open nozzle *d*, while the small evaporator pressure in the container *g* under *R* is still maintained. There, however, the lubricant meets with the cooling medium, and is forced into the container *g* through the hole *h* and isolating valve *k*.

The article describes further a carbon dioxide compressor and an ammonia compressor; also a double acting compressor for sulphurous acid and the Audiffren-Singrün refrigerating machine. (*Die Kälte-Anlagen an der Schweiz. Landesausstellung Bern 1914*, Professor P. Ostertag, *Schweizerische Bauzeitung*, vol. 65, no. 26, p. 289, June 26, 1915, 4 pp., 10 figs., *d*).

Steam Engineering

Pikal System of Boiler Tube Replacement.

The article describes the so-called Pikal method of tube beading used both in fire tube and water tube boilers. It is well known that whenever a tube in a boiler has to be replaced a new tube must be used, as the processes now in use do not admit of securely welding on an old tube. Further, all processes of welding-in tubes have the added disadvantage of reducing the inner diameter of the tubing, because of the overlapping at the place of welding. The Pikal method is claimed to permit of the use of old tubes without that disadvantage because as shown in Fig. 3, the use of a soft iron beading insert permits not only of the use of the old tubes but of their improvement in such a manner that they become even better than ordinary new tubes without the soft iron beading insert.

The main value of the use of the reinforced soft iron beading element lies in the fact that it is made of soft material, contrary to the usual practice, softer than the walls of the boiler tube. As a matter of fact, when hard boiler tubing is beaded into the tube wall, and the tube has a higher strength than the tube wall (50 kg. per sq.m. as against 40 kg.), the limits of expansion of the two materials are in the same ratio. As a result, the limit of elongation of the tube wall is reached earlier than that of the tube itself. Iron which has reached its limit of elongation through continued expansion is no longer elastic and tends to maintain its expanded dimensions; hence the extended bore of the tube wall retains its expansion (compare 2 in Fig. O), while the tube which is still elastic does come back to its original diameter. As a result, the tube and tube wall bore get out of touch and the tube does not sit steam-tight in the bore. A further beading is therefore necessary until the tube reaches *its* limit of expansion and in the end one has a contact between two materials, both of which are stressed beyond their limit of elasticity; which is neither permanent nor reliable.

In the Pikal process an entirely different situation is said to exist. The beading insert (tube) has a lower strength than the tube wall and therefore is the first to exceed its limit of elasticity. As a result, the tube wall even after a

comparatively long beading does not reach it at all if the process has been applied properly, and therefore remains elastic and encloses the no longer elastic end of the tube, thus creating a steam-tight and permanent contact.

Tests on the permanence of the Pikal method of locating the tube ends in the tube wall have been made at the laboratory of technical mechanics, at the Technical High School in Vienna and are said to have shown that the Pikal tube end sits tighter in the tube wall than an ordinary boiler tube. The tension in which the test piece came out from the tube wall was, with ordinary fire or water tubes, on the average 6310 kg. (13882 lb.) and with the Pikal attachments, 8320 kg. (18204 lb.). The Pikal process is especially applicable to old boilers. (*Das Pikalsche Rohrwechsel-Verfahren und seine praktische Anwendung, Der praktische Maschinen-Konstrukteur*, vol. 48, no. 23/24, p. 105 (General Section), June 17, 1915, 3 pp., 2 figs. *de*).

CALCULATION OF DIMENSIONS OF SAFETY VALVES WITH HIGH LIFT.

Discussion of methods of calculation of safety valves with high lifts. Criticism of the Cario formula and experimental proof that this formula does not give sufficiently large values in the case of high efficiency boilers.

According to German police regulations for land boilers (Section 2, paragraph 9, December 17, 1908)—"Safety valves must carry such maximum load that when the pressure stipulated for a given boiler has been reached, all steam in excess of that should be able to escape. The cross-section of the safety valves must, under normal conditions of operation, be such as to be able to allow of the escape of enough steam so that the stipulated pressure should not be exceeded by more than one tenth its amount." According to the same regulations, the cross-section of the safety valves is sufficient if determined by the following formula:

$$F = 15\,H\sqrt{\frac{1000}{p\gamma}}$$

where F is the cross-section of the valve in sq. mm H the heating area of the boiler in square meters p the gage pressure of steam in kg. per sq. cm.; γ the weight of 1 cbm. of steam at gage pressure p in kg. In the case of a high lift valve of which the lift is at least $= \frac{d}{4}$ (where d is the diameter of the valve), instead of the coefficient 15 in the above formula, a coefficient 5 may be used, but in this case the manufacturer of the valve must guarantee that the lift indicated will be available in the case of a pressure e ceeding a stipulated steam pressure by one tenth. The above formula is derived from the general formula

$$F = d\,h = \frac{D}{5}\cdot\frac{1}{\mu}\sqrt{\frac{1}{p\cdot\gamma}}$$

where h is the lift of the valve in mm; D the amount in kg. of steam generated per square meter of heating surface per hour; μ coefficient of outflow of steam. The disadvantage of the above formula is that it does not seem to take into consideration the rate of output of steam in the boiler. It does not appear reasonable to provide safety valves of the same dimensions on the combined fire tube-smoke tube boiler, and the high efficiency boiler having an output of steam three or four times per unit of heating surface as large as the former. As a matter of fact the following case shows that when the load on the heating surface of the boiler is more than 30 kg. per sq. m. per hour, high lift safety valves calculated in accordance with the above formula do not afford sufficient protection against excessive overloads.

In the power plant of the Rhine-Westphalian Electric Co. there was installed a high efficiency boiler having a heating area of 973 sq. m. and a grate area of 36.8 sq. m. It was provided with four high lift safety valves of 70 mm diameter, each sufficient to take care of excessive pressures in accordance with the above quoted police regulations. For experimental purposes, the steam outflow on the boiler was suddenly closed by an automatically operated rapid closing valve so that the entire amount of steam generated had to be let out by the safety valves. Although the latter were going full blast, the steam pressure rose to 17 atmospheres (safety limit 15.4 atmospheres) and would probably have gone up still further had not the fire been put out. In this case, therefore, even though the safety valves had been dimensioned in accordance with the police requirements, they could not prevent an excessive rise of pressure, and instead of four, six such valves had to be installed. While as a matter of fact such a situation as was experimentally allowed to take place here, would not usually be met with under ordinary conditions, as it would be only under very exceptional

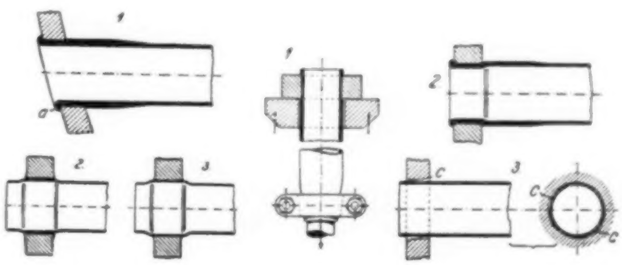

FIG. 3 PIKAL SYSTEM OF BOILER TUBE REPLACEMENT

circumstances that the entire output of steam would be cut off and the valves would have to take care of the steam generated, still it shows that safety valves dimensioned in accordance with the above formula are not sufficient to take care of the output in any high efficiency boilers. The author proposes, therefore, instead of the above formula, the following two formulae:

$$F_n = \frac{Q_{max}}{2}\sqrt{\frac{1000}{p\cdot\gamma}} \text{ for ordinary safety valves}$$

$$F_h = \frac{Q_{max}}{6}\sqrt{\frac{1000}{p\cdot\gamma}} \text{ for safety valves with high lift}$$

where Q_{max} is the maximum steam output of the boiler per hour (in kg.). In this formula the heating area of the boiler is not taken into account at all, which is reasonable because it has no uniform influence on the amount of steam generated. (*Beitrag zur Berechnung von Hochhub-Sicherheitsventilen*, Otte, *Zeits. für Dampfkessel und Maschinenbetrieb*, vol. 38, no. 22, p. 183, May 28, 1915, 2 pp. *tpe*.)

CALCULATION OF THE LAVAL NOZZLE BY THE PV DIAGRAM.

The adiabatic variation of state is given by the equation:

$$PV^k = \text{Const.} \quad\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

If we denote

$$\lambda = \frac{k}{k-1}PV \quad\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

it follows that

$$\lambda\; V^{k-1} = \text{Constant} \quad\ldots\ldots\ldots\ldots\ldots [3]$$

λ is really the heat content of the medium at the state P, V.

The constant which is missing on the right side, can be neglected since, as we are going to show later, it is not the absolute values of λ, but the difference between these values that is of determining importance.

In Fig. 4 is plotted the curve $PV^k = \text{Const.}$; for saturated steam $k = 1.135$, for an initial pressure of 10 atmospheres absolute. To do this, the Brauer method was used, with $\tan \alpha = 0.2$, and $\tan \beta = 0.23$. The curve determined from equation [3] can also be plotted by the Brauer method with a slight alteration necessary for conveniently plotting the curve. The alteration consists in that, instead of 45 deg.,

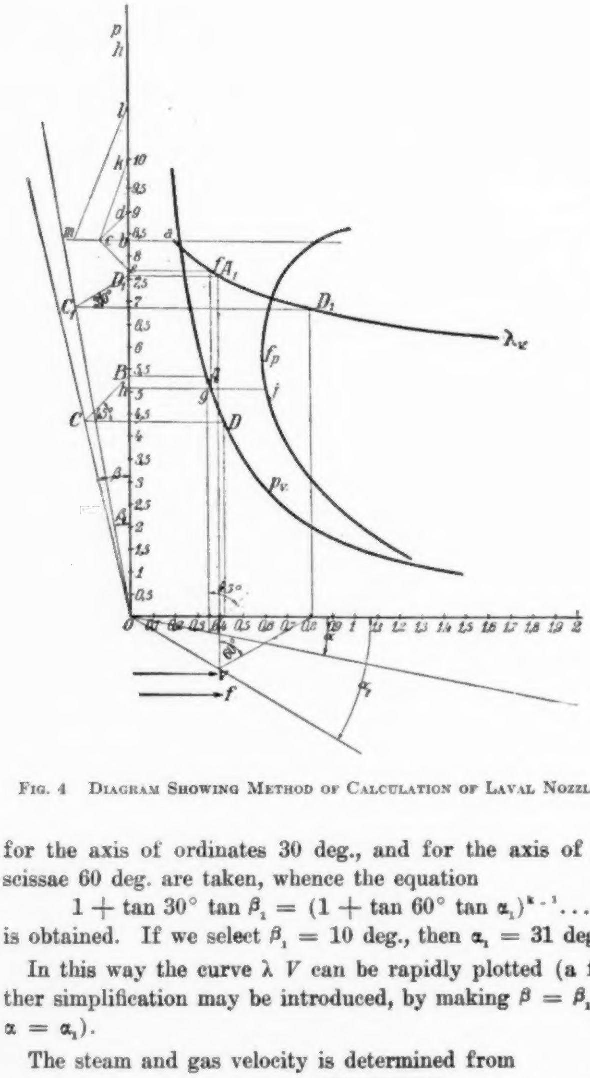

Fig. 4 Diagram Showing Method of Calculation of Laval Nozzles

for the axis of ordinates 30 deg., and for the axis of abscissae 60 deg. are taken, whence the equation

$$1 + \tan 30^\circ \tan \beta_1 = (1 + \tan 60^\circ \tan \alpha_1)^{k-1} \ldots [4]$$

is obtained. If we select $\beta_1 = 10$ deg., then $\alpha_1 = 31$ deg.

In this way the curve $\lambda\ V$ can be rapidly plotted (a further simplification may be introduced, by making $\beta = \beta_1$, or $\alpha = \alpha_1$).

The steam and gas velocity is determined from

$$c = \alpha \sqrt{\lambda_2 - \lambda_1} \ldots\ldots\ldots\ldots\ldots [5]$$

The cross-section of the nozzle

$$\frac{c}{V} = \frac{1}{f} \ldots\ldots\ldots\ldots\ldots\ldots [6]$$

From f the cross-section can be easily determined, and e. g. for a circular orifice

$$d = \beta \sqrt{f} \ldots\ldots\ldots\ldots\ldots [7]$$

The calculations of [5], [6] and [7] can be very easily carried out graphically. If we select on the axis of ordinates a point b corresponding to the origin of the $\lambda\ V$ curve, and then select on the same axis a second point d, and, starting from d, draw rectangular triangles of which the apexes of the right angles lie on the straight line ab, then it follows (Fig. 4) that

$$\frac{e\ b}{e_1\ b_1} = \sqrt{\frac{c\ b}{c_1\ b_1}} \text{ or } \sqrt{\frac{\lambda}{\lambda_1}} = \frac{c}{c_1}$$

that is, the velocities can be measured off on the line ab. If now the specific volumes $\overline{ef}$ corresponding to these points be plotted from b upwards on the axis of ordinates, a point m selected on the line ab, and from m a line equal to ml be drawn parallel to ck, then $bl = hj$ is the required cross-section. In this way can be determined the single points, and the curve fp plotted.

To determine the scale, values must be calculated for some definite point or state. The points d and m should be selected so that no sharp intersections of the lines should occur: a little practice will enable one to do this easily. (*Berechnung einer Lavalschen Düse mit Hilfe der pv-Diagramme*, Arthur Balog, *Zeits. für das gesamte Turbinenwesen*, vol. 12, no. 16, p. 181, June 10, 1915, 2 pp., 1 fig. *mp.*)

Varia

New Method of Producing Pure Compressed Hydrogen.

Until recently, hydrogen was a by-product of secondary importance, mainly burned in various ways. Of late, however, several chemical processes, such as the production of synthetic ammonia, and the use of hydrogen in autogenous welding, have created a big demand for it, by no means satisfied by the existing methods of production. The present method utilizes the decomposition of water under pressure, by iron.

Experiments in physical chemistry have shown that some elements, apparently inert, enter into various reactions under different conditions of temperature and pressure, and that the apparent inertness is really due to the low velocity of reaction, so that by changing the conditions of reaction, it becomes possible, for example, to unite apparently inert nitrogen with various elements, to introduce by means of catalysis hydrogen into unsaturated organic combinations, and finally to unite these two inert gases into synthetic ammonia. Coming more nearly to the production of hydrogen, in existing processes steam is decomposed by acting on hot iron. If, however, the reaction occurs at a low temperature, it becomes too slow. The effort of the inventor in the present instance has been to obtain the decomposition of water at as low a temperature as possible, so as to avoid contamination of hydrogen by carbon monoxide, which would make it useless for certain chemical processes; at the same time it was desired to carry on the reaction at a high speed so as to make its commercial application possible. To do this, water could not be used in the form of steam because, under 400 deg. cent., the velocity of reaction of steam with either carbon or metals is too low. Hence a new principle was applied and water was decomposed whilst in a liquid state at temperatures lying between its boiling point and 400 deg. cent. As the decomposition was carried on by means of carbon, what was practically obtained was burning carbon under flowing water. The reaction occurred in accordance with the formula

$$C + 2\,H_2O = CO_2 + 2H_2$$

which shows that hydrogen and carbon dioxide were obtained in the correct stoichiometric ratio. In its simplest form, the reaction, however, goes on very slowly. But other observa-

tions have shown that the reaction between water and metals, especially iron, is very highly affected by the temperature, which the author explains by the fact that within the region of temperatures used, the water is already nearly split into two ions, H and OH. The H ion helps the iron to pass into solution and the comparatively high concentration of OH then produces an immediate settlement of the iron ions in the form of an insoluble oxyduloxide. The hydrogen ions are then liberated as free hydrogen. This reaction is materially speeded by the presence of some electrolyte in the water or by contact of the reacting substances with some noble metal.

Experiments on small vessels have shown that by the application of this process, it is easy to have hydrogen continually discharged from the vessel under high pressure without permitting the water of reaction to come out from the vessel in the form of steam. The apparatus used for tests on a small scale is diagrammatically shown in Fig. 5. The vessel in which the reaction occurs is provided with a conical stopper, a narrow pipe serving as a return cooler. To this pipe is connected a second small vessel, the purpose of which is to catch water drops carried over by the gas mechanically while other piping leads to a high pressure container in which the hydrogen developed under high pressure is kept stored up. The experimental apparatus was filled with iron powder, water and some electrolyte and then heated up. Hydrogen was developed under a working pressure of 300 atmospheres, which happens to be a convenient pressure for use in various chemical processes where there is a demand for this gas.

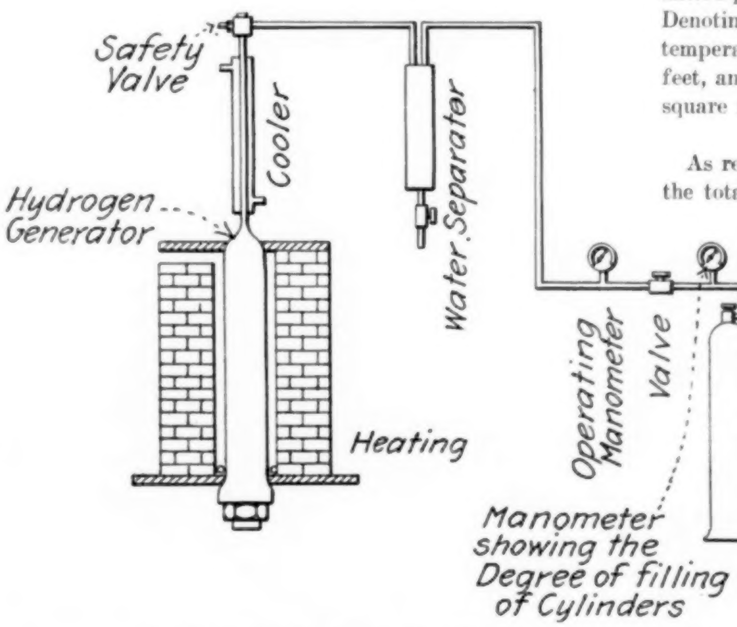

FIG. 5 BERGIUS ARRANGEMENT FOR THE GENERATION OF HYDROGEN

The entire process requires only coal and water and compressed hydrogen is obtained without the utilization of special compressing plant. The hydrogen is stated to be purer than any other kind directly obtainable. (*Eine neue Methode zur Herstellung reinen komprimierten Wasserstoffs*, Dr. Fr. Bergius, *Zeits. für komprimierte und flüssige Gase*, vol. 17, no. 3, p. 33, March 1915, 6 pp., 3 figs., *d*).

ENGINEERING SOCIETIES

AMERICAN SOCIETY OF NAVAL ENGINEERS

Journal, vol. 27, no. 2, May 1915, Washington, D. C.

Heat Transmission and Tube Length in Marine Feed-Water Heaters, Leo Loeb (abstracted)
Steam Turbine Blade Fastenings, Jas. A. Capstaff
Possible Application of the Drzewiecki Method to the Design of Water Propellers, H. E. Rossell
The Pneumercator, Henderson B. Gregory

HEAT TRANSMISSION AND TUBE LENGTH IN MARINE FEED-WATER HEATERS.

Investigation of the theory of heat transmission in feed water heaters and the elements affecting it. Reports of tests on Bureau of Steam Engineering heaters and Koerting film heaters.

Heat resistance is best measured in terms of its reciprocal, K, thermal conductivity, the number of heat units transmitted per unit of area across a given space per unit of time. Denoting by Q heat transferred per hour in B.t.u., t_m mean temperature difference, S area of heating surface in square feet, and K rate of heat transmission in B.t.u. per hour per square foot per degree of temperature difference, we have

$$Q = S\,K\,t_m$$

As regards the nature of K, it must be borne in mind that the total thermal resistance is dependent upon two film resistances, scale, and metal wall resistance. Proper preparation of the tube material and proper up-keep and operation will eliminate the scale condition. There are quite comprehensive data on the magnitude of metal wall resistance, which show that the temperature difference on the two sides of the metal tube is very small. Tube material or tube thickness only slightly impedes heat flow and a water film 0.00173 in. thick will give the same resistance as a 1-in. thickness of copper tube. It is evident, therefore, that a metal tube will transmit all the heat that is presented to its surface and the controlling resistances lie in the two films which cling to the metal surfaces, the resistance on both sides being much alike because the condensing steam presents a wet surface. The formation of such a film on the water side is a friction effect, the microscopic irregularities of the surface of the metal walls preventing the particles of water from being swept along with the major current. Hence the problem in producing high transmission in heaters is the destruction of this water film by a scrubbing action which may be produced by a high velocity along the heating surface, and after the limit of heat transmission has been reached on the water side by a velocity within practical limits, the controlling resistance passes to the steam side, so that the only way to further increase heat transmission is to sweep away the film on the steam side.

A factor in the heat transfer equation of equal importance with the coefficient of conductivity is temperature difference. It can be increased in but one way; by raising the temperature of the heating medium. Further, it is found that the increase in exhaust temperature obtained by throttling the auxiliary exhaust is also of some value.

The author then discusses types of temperature gradients resulting from various assumptions as to the functional dependence of heat transfer—for example, when a transfer is at any instant proportional to the temperature difference. He gives an analysis for this case and the curve obtained when inlet and outlet temperatures for a given steam pressure and water velocity are known. He shows, however, that

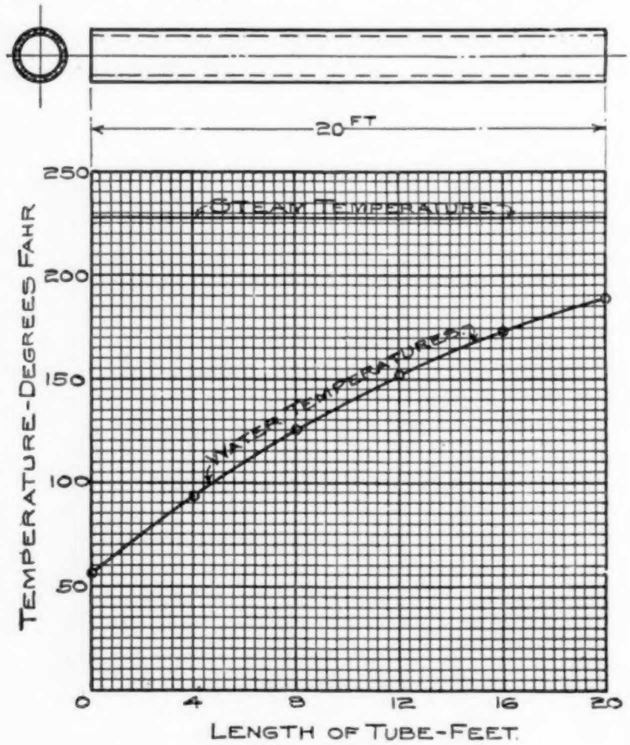

Fig. 6A. Temperature Gradient in a ¾ in. Copper Tube.

the analysis given would be very satisfactory were it not for the fact that there exists considerable experimental evidence that heat transfer in feed heaters is not directly proportional to temperature difference, and he proves it by results obtained from a single tube experimental heater tested under his own direction at the Engineering Experimental Station.

This heater consisted of a single ¾ in. copper tube, No. 18 B. W. G., 4 ft. long, secured within a 4 in. pipe which forms the steam space. The inlet could be regulated to any desired temperature by an auxiliary heater and the temperature gradients of any given water rate are determined by noting the inlet and outlet temperature at 3 min. intervals for a period of 18 min. In this way, in a heater the length of which could be varied to suit temporary conditions of velocity, the temperature could be determined at 4 ft. intervals. Table 2 gives data from a typical set of tests with the steam pressure of 5 lb. gage and the water velocity of about 4 ft. per sec.

The gradient corresponding to columns 2, 3 and 4 is plotted in Fig. 6A. Although the temperature rise per pass varies from 15.4 to 37.8, the average arithmetical temperature difference may be very closely considered to be the mean temperature difference per pass, since the curvature of the temperature gradient is very slight and the straight line connecting any two points varies only slightly from the best smooth curve through the points.

The relation between temperature difference and heat transfer per hour, columns 5 and 7 of Table 2, is plotted on logarithmic cross-section paper (Fig. 6C) and these points fall quite accurately on a straight line, which is equivalent to saying that heat transfer in feed water heaters is proportional to some power of the instantaneous temperature difference which may be expressed analytically as

$$Q = K\,S\,(t_s - t)^n$$

where n is the slope of the line on the logarithmic curve, in this case, a value somewhat less than unity.

From this the author derives the following formula

$$t_m = \frac{(1-n)\,(t_o - t_i)}{(t_s - t_i)^{1-n} - (t_s - t_o)^{1-n}}$$

which is the same as that derived by Mr. Orrok for condensers, but is obtained from the basic experimental proof that heat transfer is proportional to a power of the temperature difference instead of the secondary fact that the rate of heat transmission per degree of temperature difference is proportional to a power of temperature difference. This latter method is more involved, inasmuch as it introduces another variable factor U, which varies with temperature, and there is a decided disadvantage in obtaining U as function of t because the whole purpose is to obtain an experimental value of K which will remain constant throughout the heater design in question. A comparison of the two laws of temperature variation for the range of data in Table 2 is shown in the curves of Fig. 6B. The lines A, B and C are the gradi-

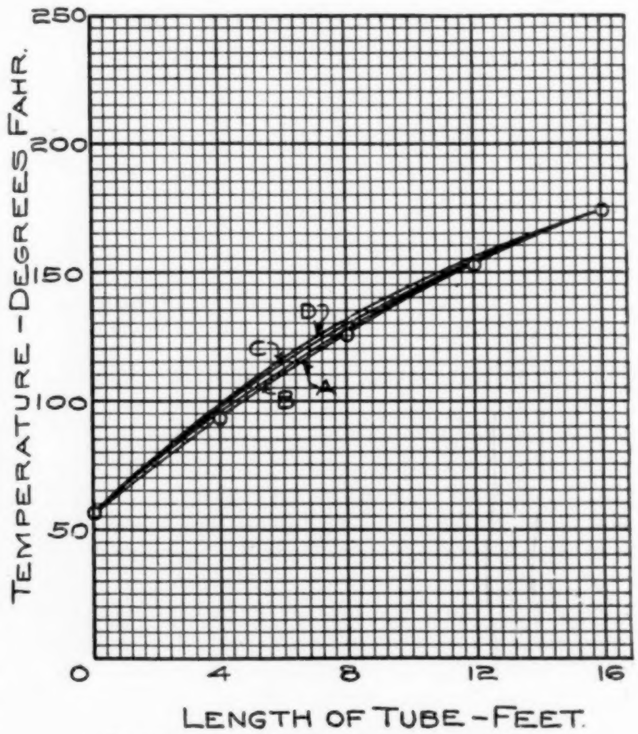

Fig. 6B. Curves Showing a Comparison of the Two Laws of Temperature Variation.

ents from the relation $l = c\,(t_s - t)^n$ where the values of n are 0.7, 0.8 and 0.9. The line D is the gradient from the relation $l = C \log_e (t_s - t)$ and the semicircles mark the inlet and outlet points in columns 2 and 3 of Table 2.

Tests of Heat Transmission in Marine Heaters. The above established general law for heat transfer was applied by the author to the test of heaters used in the naval service, two

types having been exhaustively investigated—namely, a feed heater designed by the Bureau of Steam Engineering for battleships 34 and 35, and incidentally used in evaporator plants on board ship; and a spiral corrugated film heater manufactured by Schutte & Koerting.

The Bureau feed water heater consists of a composition shell containing 117 semicircular ¾ in. tubes, No. 16 B. W. G. expanded into a composition tube sheet and a cast-steel bonnet, cast so as to form separate passages over the two ends of the tubes. When used for feed heating, the feed water passes through the tubes and the steam circulates in the outer casting. The total heating surface is 88.2 sq. ft., of which 86 sq. ft. is tube area. The net area through the water passage of tubes is .362 sq. ft. The data on these tests are only very briefly reported here because they were published in full in the Journal of the American Society of Naval Engineers, February 1912, pp. 155-166.

The tests were divided into two main groups, dependent upon the inlet temperature maintained at about 80 deg. fahr. in the first case and from 130 to 150 deg. in the second, with further subdivision, according to feed velocity and steam pressure. The mean water velocities chosen were 35, 71, 107, 143 and 171 ft. per minute. The steam pressures were 5, 10, 15 and 20 lb. gage and the water pressure was held at over 230 to 250 lb. gage. The tests show in general an increase of heat transfer with steam pressure and with velocity, but a decrease at the same pressure with increasing temperature difference. There were, however, irregularities in data which cast doubt on the results.

In some of the tests the tubes were fitted with retarders consisting of annealed copper strips ⅝ in. wide and 0.0268 in. thick, twisted into a spiral of 6 in. pitch. The dropping pressure through each pass of the heater is measured by a differential mercury gage, 0.55 in. of mercury without retarders as against 0.98 with retarders, which shows that the introduction of the retarders involves no serious increase in friction. The author finds that, for the heater in question, the heat transfer-temperature relations is given by $Q = K\ (t_s - t)^n$ where Q = B.t.u. per hour per sq. ft. of heating surface; K = a constant from experiment; t_s = average saturation steam pressure within the heater; t = water temperature; n = a constant from experiment. Furthermore, n is the slope of the curve on the logarithmic plot and has for this heater a value $n = 0.85$, which is independent of the velocity and of the use of retarders. The value of K, however, which is the intersection of the line prolonged and the vertical axis when $(t_s - t) = 1$ is dependent on the velocity and is therefore the function which varies with the greater or less removal of the water side film. The use of retarders has the same effect as increasing the velocity by increasing the value of K.

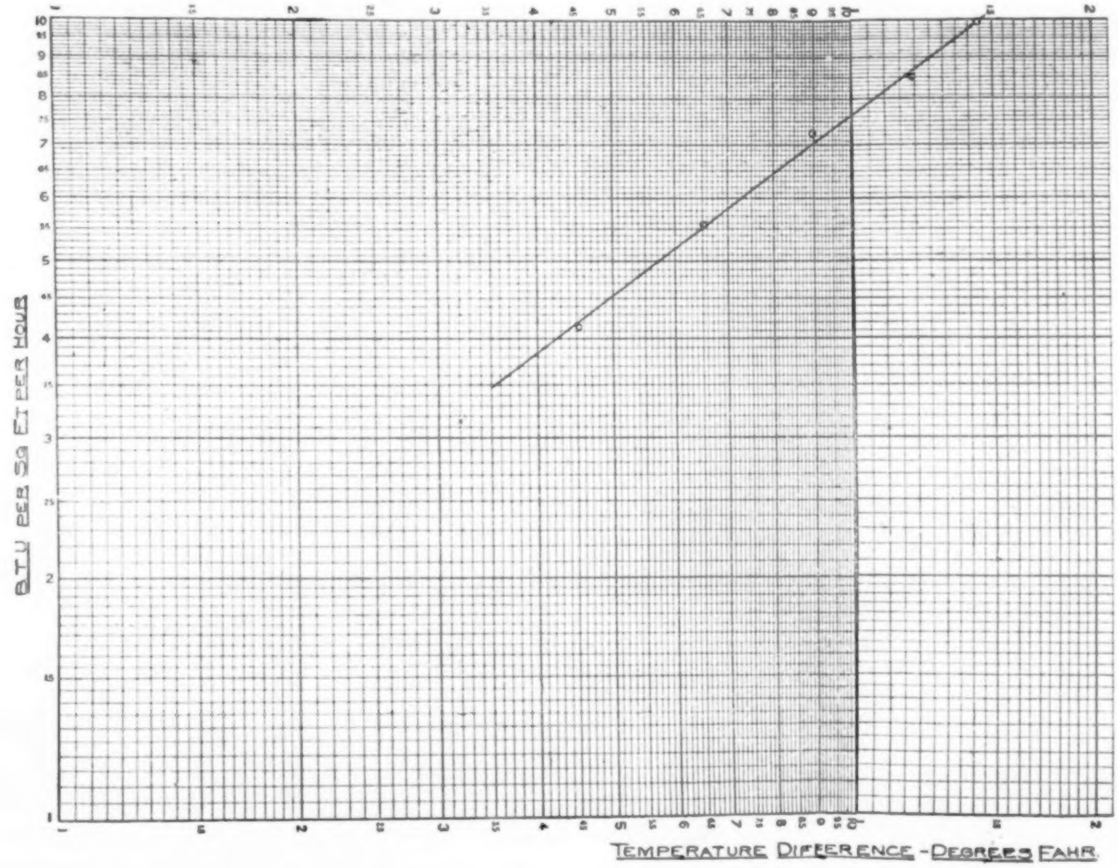

Fig. 6C. Heat Transfer—Temperature Relation of a ¾ in. No. 18 B. to Y. Tube.

From data derived by Clement and Garland and published in a bulletin entitled "Study of Heat Transmission" (University of Illinois Engineering Experiment Station, Bulletin No. 40), the author comes to the conclusion that in a feed heater, the controlling resistance lies on the water side and is subject to correction by a mechanical agitating or mixing device up to the point where water ceases to flow as a uni-

form fluid, the point known as the critical velocity of the fluid.

As regards the use of retarders, the present tests have shown that in the Bureau type of heater, the introduction of the spiral retarders increased, at the water rate of 1500 lb. per tube per hour, the heat transmission by 16 per cent; at 2000 lb., 7.5 per cent; at 2500 lb., 14.9 per cent, and at 3000 lb., 14.8 per cent.

Further tests were made on a Schutte & Koerting spirally corrugated film heater of the usual type. In this heater, the water flows through in a 7/64 in. thick nominal film between two corrugated tubes, the steam circulating downward around the outer tube and within the inner tube. When the heater was put into service it was found that the least practical rate of discharge was 7500 lb. of water per hour, for at lower rates the outlet water was at such a high temperature that much of it was flashed into steam beyond the outlet control valve. As a result, the rates of discharge selected for this purpose were 7500, 10,000 and 15,000 lb. per hr.

The heat transmitted in B.t.u. per square foot per hour was found to reach a value of 147,922 lb. at the highest velocity, which corresponds to a heat transmission per square foot per hour per degree average temperature difference of 1.227 B.t.u., or more than double that obtained at equivalent velocities in the Bureau type of heater. However, the true velocity of water in this heater is not certain as the spiral corrugation will produce an agitation greater than direct flow through a uniform film of the same area. In every case the axial velocity was considered and the velocity corresponding to a reasonable friction loss would be about 250 ft. per minute, or 12,930 lb. of water per hr.

A small experimental heater of this type was tested at the Engineering Experimental Station in Annapolis in 1912. The experimental apparatus involved four pairs of spirally corrugated tubes arranged in two passes, the film thickness in the design finally adopted being approximately $\frac{3}{16}$ in. The heater was initially designed for horizontal installation, but a slight modification of the lower header permitted of vertical mounting. The article describes in detail the experimental apparatus and method of conducting the tests. No practical way was found to give an accurate temperature of the water at the reversal of flow in the lower head; hence a temperature gradient could not be constructed and the value of n (exponent in the heat transfer relation) had to be determined indirectly. Since the temperature rise of test was usually in excess of 100 deg., the average temperature difference would not be close enough to the mean temperature to obtain the value of the exponent directly from the logarithmic plot.

It was found that only a slight advantage can be gained from water film agitation above 7500 lb. per tube per hour. This must be considered as the critical velocity for such construction and higher rates would produce no increased heat transfer, but would result in excessive friction losses. As regards the relation between the vertical and horizontal heaters of the same film thickness, at 500 lb. of water per unit of surface, the horizontal heater shows rates of heat transmission of 720 B.t.u. per hr. per degree of temperature difference as against 910 B.t.u. for the vertical heater, an advantage of 26.4 per cent. in favor of vertical installation. Care was taken to give the horizontal heater sufficient pitch to cause the water of condensation to flow freely from the tubes. This did not entirely accomplish the desired results, as the weights of condensed steam for the several intervals of any one test vary between wide limits, whereas in the vertical heater these quantities remain remarkably constant. The great difference between the performance of the horizontal and vertical heaters cannot, however, be entirely accounted for by the accumulation of water of condensation in the lower part of the corrugations of the inner tube, but the reason for the difference is to be found in the accumulation of air in the steam space, which cannot be eliminated by blowing through pet cocks in the covers. The presence of this air would actively reduce the transmitting surface, and this, taken with the irregular flow of water of condensation, would explain the variation. In a subsequent test, a more efficient disposal of air, attended, however, with a considerable loss of steam, resulted in rates of heat transmission of about 5 per cent less for the horizontal than for the vertical installation.

In the case of a 7/64 in. film vertical heater there is a noticeable lack of uniformity between the friction losses for high and low rates of flow, while the $\frac{3}{16}$ in. film gives uniform values of friction loss under widely varied temperature limits, and possesses the further great advantage of the re-

TABLE 2 TEMPERATURE GRADIENT IN A 3/4 INCH COPPER TUBE

Outside tube diameter, inches	.750
Inside tube diameter, inches	.655
Length, feet	4.0
Water-heating surface, square feet	.6853
Steam-heating surface, square feet	.7873

No.	Steam Temperature, Deg. Fahr.	Water Temperature, Deg. Fahr.		Average Temperature Difference	Water Heated per Hour, Pounds	Heat Transfer B.t.u. per Hour per Sq. Foot Steam Surface
		Inlet	Outlet			
1	2	3	4	5	6	7
1	228.4	55.6	93.4	143.9	2,070	99,060
2	228.0	93.2	125.2	118.8	2,095	85,039
3	228.4	125.1	152.3	89.7	2,106	72,771
4	228.1	152.5	173.4	65.1	2,120	56,007
5	227.3	174.4	189.8	45.2	2,106	41,453

placement of tubes without danger of change in adjustment sufficient to modify the nominal film thickness.

The author suggests, therefore, the standardization of the $\frac{3}{16}$ in. film vertical heater as being advisable, besides the important consideration of minimum friction loss, also because of equal heat transfer per unit of heating surface, efficient removal of water of condensation and non-condensible gases from contact with the heating surface, and ability to maintain a uniform film thickness when assembling the units (55 pp., 20 figs. *etA*).

THE CONCRETE INSTITUTE

Transactions and Notes, vol. 5, parts 3, 4, 5, 6, April, 1915, London

Some Fallacies in Cement Testing, W. Laurence Gadd (abstracted)
Factory Construction in Reinforced Concrete, Percival M. Fraser
Standard Method of Measurement for Reinforced Concrete (report)
Calculations and Details for Steel-Frame Buildings from the Draughtman's Standpoint, W. Cyril Cocking
Forms for Concrete Work, Allan Graham
The Design of Steel and Reinforced Concrete Pillars, with Special Reference to Secondary and Accidental Stresses, Oscar Faber
Sand and Coarse Material and Proportioning Concrete, John A. Davenport and S. W. Perrott

Some Fallacies in Cement Testing

The paper discusses what the author refers to as fallacies in cement tests, or more precisely, various possible sources of error affecting the reliability of results obtained from such test. He starts with the stipulation of the British Standards Specification, that before any sample of cement is submitted to certain tests, " it shall be spread out for a depth of three inches for 24 hours in a temperature of from 58 to 64 deg. fahr." One of the possible objects of this procedure was to obtain conditions similar to those governing cement which has lain in sacks or casks for two or three weeks. In order to test the effect on certain types of storage in sacks, the author tested three sets of samples from specimens dispatched to him at the time of the filling of the sacks, and found that in the majority of cases, the cement became quick in initial setting after storage in sacks for 14 and 28 days, with some exceptions. The final setting was in some cases slowed and in others quickened, but it is impossible to generalize on the results so that the only thing one can say is that cement kept in sacks, under ordinary conditions of dry storage, may either become slower or quicker setting, but the results cannot be foretold.

Tests were also made to determine the effect of aerating in layers three inches deep. It was found that the setting time, tested in accordance with the British Standards Specification, does not agree with that of the bulk sample which it is supposed to represent. There is no relation between the effects of aerating cement for 24 hours and storing in sacks for two weeks or a month; the setting time is differently affected when the same cement is aerated or stored in bulk in different localities or at different periods. Changes in setting time are not due to some inherent property of different cements. The erratic behavior found is common to all the samples tested, the composition of which vary with considerable limits. The retardation or acceleration of setting time on storage or aerating must be due, therefore, to chemical changes brought about by the absorption of some constituents present in the mixture. To test this, a quantity of slow-setting cement was placed in a large glass tube and a current of purified air, free from ammonia, carbonic anhydride and moisture passed over it continuously for 24 hours. It was found that pure dry air had no effect upon the setting time of the cement, the loss constituents remaining practically constant. On the other hand, the effect of moist air, free from carbonic anhydride, was distinctly marked, although the percentage of moisture absorbed was comparatively small. The acceleration of setting time by carbonic anhydride was also clearly proved.

The author discusses also the question of fineness of cement in tests, and the exactness of the mesh of the sieve. He finds that sieves which conform to the British Standards Specification often give, in testing, most erratic results. Further, the size of the sieve itself has been overlooked, which is important because the same weight of cement, sifted for the same period of time will be more effectively sifted over a large area than over a small one. (Proved by actual experiment.)

The specific gravity test still retained in the British Standards Specification, is considered to be a test for underburnt cement, but gives really no indication of the degree of calcination. The author's experience is that, when cement is taken freshly from the kiln, the specific gravity is practically the same whether the clinker be well burned or underburned, provided the carbonic anhydride has been all, or nearly all, expelled from the chalk. The author thinks, therefore, that the test should not be retained because, first, the direct method of estimating the loss on ignition is more accurate than a determination of specific gravity, and second, an artificial cement, especially if finely ground, exposed to air, but kept in a damp store for some time, may have its gravity reduced to a figure quite as low as that of many natural cements. The only certain guide by which to determine whether a sample is or is not a natural cement is a chemical analysis and with the data this gives, the specific gravity becomes superfluous.

Tensile or crushing tests of cement with standard sand do not represent, in the opinion of the author, the best results of which the cement is capable but give results which are standardized and therefore comparable with those obtained by different operators. The crushing strength, especially of concrete or mortar, depends largely upon the size and character of the aggregate, the absence or presence of dust and clay matter, and the density of the mass. Experiments made by the author have shown that the crushing resistance of concrete, made from the same cement, varies not only with the size but also with the character of the aggregate.

The author is distinctly against the use of the so-called autoclave test, and claims that to show the utility of such a test it must be shown, further, that the cement which passes the simplest soundness tests generally employed will yet be dangerous in ordinary work, and second, that the autoclave test will detect such cements with certainty, neither of which points have been demonstrated so far.

Finally, the author rejects the widely accepted theory that unsoundness of cement may be due to free lime locked up within the particles of the ground material. The improvement in soundness brought about by the exposure of cement to a damp atmosphere might lend some apparent support to the contention that the freed lime is thereby slaked and rendered harmless; but he fails to see how the small amount

of moisture absorbed from the air penetrates the particle and slakes the free lime when the enormously larger quantity of water used in gaging the cement fails to do it. Furthermore, unsound cement stored for some time in air-tight receptacles, in which presumably no slaking of free lime can occur, still becomes perfectly sound. Finally, it is a well known fact that low-lime cement is often more unsound than high-limed cement, which is again antagonistic to the free-lime theory. The author's view is that unsoundness in cement is probably due to the presence of an abnormal silicate perhaps dicalcium silicate, which is an unstable compound and slowly disintegrates with an increase in volume (18 pp., *g*).

TENTH ANNUAL CONFERENCE ON WEIGHTS AND MEASURES

AUTOMATIC SCALES, F. J. SCHLINK

The paper, read before the Tenth Annual Conference on Weights and Measures of the United States, May 26, 1915, is abstracted from an advance publication in *The Scale Journal,* (Vol. 1st, No. 9, June 25, 1915, Chicago, Illinois).

The author divides weighing scales into two classes; viz., scales in which the weight of the load is determined by the manipulation of suitable balancing or equilibrating means, through the agency of an operator, and those in which the weight is obtained by merely placing the load to be weighed upon the scale and reading the indication of some self-actuated mechanism. Automatic scales, which is the generic name of scales of the second class, may be of many forms, such as scales in which the reading is obtained directly through the agency of a variable equilibrating element dependent in its action upon the magnitude of the load being weighed; scales which perform repeated weighings of a definite amount of commodity which, though fixed for a single setting of the scale, may be adjusted within a certain range (package scales or dumping scales).

As a means for obtaining automatic indications may be used either an elastic body, the deformation of which bears some known relation to the external force applied to it, or a system of non-elastic bodies having a definite configuration for a given magnitude and direction of the forces which are applied to it. The first class is exemplified in spring scales of which the helical or screw spring scale is the most common. All forms of springs are, however, subject to certain changes which affect their utility as weighing elements; among these changes are, first, imperfect elasticity, which results in the slight differences in the elongation of the spring at a given load, depending upon whether the load is being increased or decreased, and also upon by what are called fatigue effects; the effects of imperfect elasticity can be reduced to a minimum by using the spring at a low working stress. Second, error due to change of elastic properties and dimensions of the spring with temperature. This may be corrected or avoided by one of several methods, such as automatically changing the ratio of the leverage as the temperature changes. Another method is to keep the spring at a constant and definite temperature, and finally, to use springs made of special alloy steels.

Pendulum scales, strictly speaking, include also the lever system of an ordinary beam scale. The author describes in detail the pendulum scale in its simplest form, and the cam pendulum scale. The following considerations have affected the design of such scales: if the reading chart of a pendulum scale is divided into intervals which are not uniform, any change of level of the scale taking place in the plane of the pendulum will cause the pointer to start from a different point, and if the scale be rebalanced without being releveled, it will read inaccurately. If, on the other hand, the graduations are uniformly spaced, a slight shift of the level of the scale only changes the zero region of the pointer and an adjustment of the balance by the means provided for that purpose will cause the scale to read correctly. In practice, however, the frequent adjustment of the zero balance becomes troublesome and to avoid it, the double pendulum construction is used and a weighing scale practically free from changes of balance or weight indication from small shifts of level is obtained.

The third type of equilibrating element is the cam mechanism, which is an extension of the familiar wheel and axle principle. The author describes it in detail. The cam principle is frequently employed in connection with the pendulum system, and in many cases it is difficult to distinguish sharply between cam and pendulum scales.

Every pendulum scale in which the uniformity of graduation interval is secured by means of a cam and wrapping connector is an illustration of such a combination.

In a pendulum scale having a single pendulum there is generally no cam, or only one. In a cam scale there are two, one for connection to a counterpoise and one for connection to the platform levers or weight receiving system. To add the pendulum principle to such a cam system it is only necessary to establish the center of gravity of the cam outside the center of rotation. Then the applied weight of the load is resisted not only by the fixed weight of the counterpoise, but also by the weight of the cam body itself, acting also at a variable distance from the axis of rotation. There are, then, in action, two resisting forces, each obeying a different law, and to have equally-spaced graduation, the cam must be made of such contour as to suit the combination of these two effects. Practically, this means that in the construction of a scale which is intended to act upon the cam principle alone, there should be added a small weight, adjustable on an arm extending out from the cam body, so that, by shifting the arm and the weight upon it, the center of gravity of the cam body may be brought into the axis of rotation. Conversely, the center of gravity may be intentionally shifted outside the axis of rotation any suitable amount, in order to take advantage of the corrective effect which can thus be obtained.

From this, the author proceeds to the description of other parts of the automatic scale, such as the load receiving mechanism, i. e., the lever system, the indicating mechanism, and auxiliary devices, such as the damping and relieving mechanisms. The writer expressed a belief that, in the future, automatic scales will find a continually widening application in mercantile and industrial service, while modern methods of design and manufacture are sure to bring forth refinements in construction and extension of utility (6 pp., 7 figs. *dg*).

FARADAY SOCIETY

Transactions, vol. 10, parts 2 and 3, May, 1915, London

The Vapor Pressure of Liquids in Presence of Gases, F. H. Campbell

The Hardening of Metals. A General Discussion (abstracted)

Opening Address, Sir Robert Hadfield

Introductory Paper, G. T. Beilby

The Influence of Allotropy on the Metastability of Metals, and its Bearing on Chemistry, Physics and Technics, Professor Ernst Cohen
The Part Played by the Amorphous Phase in the Hardening of Steels, J. C. W. Humfrey
The Hardening of Metals by Quenching, Professor C. A. Edwards
The Hardness of Solid Solutions, Cecil H. Desch
Note on Crystal Twinning and the Martensitic Structure, Cecil H. Desch
The Interstrain Theory of Hardness, Andrew McCance
Hardening With and Without Martensitization, Professor Henry M. Howe
The Hardening of Steel, Professor J. O. Arnold

The Hardening of Metals

A general discussion of the subject of the hardening of metals, at the Faraday Society, on November 23, 1914, in order to afford an opportunity for a further and fuller discussion of this important subject, somewhat briefly taken up at the last meeting of the Iron and Steel Institute.

Sir Robert Hadfield, in the chair, opened the discussion by a brief introduction in which, among other things, he spoke of a specimen of steel found in India, on good authority dating as far back as 125 B.C. Its interest lies in the fact that it is probably the first specimen of that age containing as much as seventy per cent carbon, which indicates that it can be readily hardened by heating and quenching in water. The material has been in its present condition for probably more than 2,000 years and now, after being heated and quenched, hardens exactly as if it had been made only yesterday, thus showing that notwithstanding this long interval and high surface oxidation, this specimen has undergone no secular change of structure or alteration in the well known capacity of an alloy of iron with carbon to harden under certain conditions.

Doctor G. T. Beilby read a paper on the hardening of metals, in which he indicated in a brief and general manner how hardening occurs and to what it is due.

Professor Ernst Cohen, of Utrecht, presented a paper on The Influence of Allotropy on the Metastability of Metals and Its Bearing on Chemistry, Physics and Technics. The paper reports an extensive and highly interesting investigation on electrolytic transformation of metals, in particular of bismuth, cadmium, copper, zinc, antimony, sodium, potassium and lead. The investigation as carried out involved the use of a pycnometer and dilatometer and of the electric potential method.

In previous experiments on bismuth, the writer found that metals may show very great retardation in undergoing molecular changes at temperatures either above or below their transition points. This reluctance to undergo change is probably one of the reasons why the phenomena observed by the writer have remained undiscovered until now. The experiments have shown that the same applies to cadmium; that cadmium is further able to undergo a reversible transformation; that apparently there may be several transition points at various temperatures and that it is very difficult, if not impossible, to fix the real transition point of the pure modifications. In order to prepare a sharply defined modification of cadmium, avoiding high temperatures, an extensive investigation of the electrolytic method, of considerable value in other directions, has been carried out. It is not reported here, however, because of lack of space.

As regards the phenomena observed in the investigations on cadmium, lead, bismuth, copper, zinc and antimony, the author concludes that the pure metals as we have known them until now, are metastable specimens consisting of two or more allotropic forms, which is a consequence of the very strong retardation which accompanies the reversible change of these allotropic modifications below and above their transition points.

The existing data on the physical constants of metal, unknown until now, are thus considered as entirely fortuitous values depending upon the previous thermal history of the material used. The physical constants which refer to a well defined condition of the metal are so far unknown, and as the phenomena described by the author have been unknown up to the present, metallurgists have not been able to take them into account in studying the hardening of metal, and yet these reversible transformations which often go on very slowly in consequence of the retardations mentioned above, must play an important role when the metals are subjected to changes of temperature. This role may become fatal if the metals are in contact with electrolytes (water, for instance) as this accelerates enormously the transformation velocity.

In an appendix, the author discusses further the question of heats of transformation of metals and the specific heats of different metals at different temperatures. Although the metals used by the author were of high purity and *cast,* which would indicate that the condition of the material was definite, it was found that previous heat treatment must still be taken into account and the values for the specific heats of these metals must be considered as fortuitous. From experiments on sodium it was found that sodium can be either monotropic or enantiotropic (a fact which was not previously known), and that it is possible to obtain at least a nearly quantitative yield through this stable or metastable solid modification from a metallic grade.

J. C. W. Humfrey presented a paper on the subject of the amorphous phase in the hardening of steels, in which he offered an explanation of the hardening of steels, using as a basis data of recent experiments upon the reflection of X-rays from crystal surfaces. The theory of crystal structure, as now accepted, asserts that the regularity of crystal structure within a crystal is two-fold, viz.:

a The centers of gravity of the molecules are arranged together according to one of a series of geometrical devices called "space lattices," in which each point in the lattice is surrounded by a similar distribution of other points.

b In each molecule of a crystal, the atoms are similarly situated.

The author considers that it is the second form of regularity which essentially gives rise to the first; or in other words, that in crystallization from fusion, it is the forces exerted by each molecule upon its neighbors (i.e. forces due to the resultant reactions of its atoms), which bring about the space-lattice structure of the crystal. The allotropic change must be considered as being essentially accompanied by a change in the internal structure of the molecule; e.g., a reorganization of the atoms composing them or a change in their number. Before this reorganization can be completed, however, there must be at least a temporary state of disorder, and it is during this disorder that the author considers that the structure must be looked upon as amorphous, and the intermediate amorphous state may be realized as corresponding to the liquid which would be formed by the fusion of the solid phase, stable at the lower temperature.

if the conditions could be so adjusted that the subsequent recrystallization were avoided. In certain cases, such phenomena can be actually observed, e.g., in the case of sulphur the changing from the monoclinic to the rhombic and back again normally occurs at the temperature of 95.6 deg. cent. In the case of iron, the temperature-tenacity curves obtained by Rosenhain and the present writer give strong indications that a similar phenomenon might occur and that if on heating a sample of iron, suitable conditions of pressure would be applied which prevented recrystallization to the γ, then a true melting point would be observed in the neighborhood of 900 deg. cent. That a second crystalline phase may form after the first is broken down to amorphous necessitates the condition that the mass is not too viscous or that it forces the crystallization to overcome the viscosity and to marshal the molecules into their new orientation. Beilby proved that such a condition is not invariably present, since any amorphous phase formed by severe overstrain in the cold possesses a definite stability up to certain well-marked temperatures and only passes back into the crystalline state when these temperatures are exceeded. In a metal in which an allotropic change normally takes place at a temperature well above that at which the viscosity is sufficient to prevent crystallization, abnormal conditions, such as rapid cooling, may delay the change to well below this temperature.

From experimental data it was found that while in the case of pure iron there is a range of about 400 deg. cent. between the temperatures at which the breakdown of the γ iron occurs and that at which the recrystallization of the α iron becomes difficult, yet in the case of an 0.9 per cent. carbon steel, the range is reduced to less than 200 deg. cent. The probability of retaining by sudden cooling some of the amorphous phase formed by the breaking down of the γ structure is therefore much greater with increasing carbon contents. Another factor causes the presence of carbon to still further promote the retention. Above the changing point, the carbide is in solid solution in the austenite, and when this phase breaks down to amorphous, the carbide molecules will still remain closely intermingled with those of the α iron. But before the amorphous can recrystallize, the two different kinds of molecules have to segregate, since the carbide is not soluble in either α or β iron. Such segregation must necessarily be a slow process in an uncooled viscous mass and rapid cooling may easily allow the minimum temperature of crystallization to be passed before it has had time to take place.

SOCIETY OF ENGINEERS

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Some Future Developments in Heating and Ventilation, A. H. Barker

A general discussion of the development of heating and ventilation with an exposition of the underlying difficulties in its way, and some suggestions as to the ways of overcoming them.

In the author's opinion the main difficulty in developing heating and ventilating engineering on a strictly scientific basis lies, first, in the great complexity of the problems with which one has to deal in every individual case, and next, in the fact that the object of both heating and ventilation, though primarily physiological, is also to some extent psychological. It is necessary to keep the inhabited rooms healthy, but of almost equal importance is the necessity of keeping them comfortable. Some physiologists say that it is desirable, in the interest of health, that the temperature maintained shall be as low as a human being can endure without real discomfort, while others claim that the rooms should be so warm that the man feels comfortable without any effort. No one can tell, say within 300 per cent. how much fresh air per head per hour is the minimum consistent with health, and the matter becomes still more complicated because of the baffling fact that a man is comfortable when he thinks he is comfortable; if we can make him imagine he is comfortable, without the alteration of any single condition, we can make him feel comfortable.

The room filled with air which is perfectly pure, as far as chemical analysis can detect, may *feel* very stuffy; for instance, the House of Commons' air in the debating chamber is chemically speaking as pure as in any room in the world, yet it produces without any possible doubt the lassitude and sleepiness, infection, etc.,—effects which we are accustomed to think of as connected with defective ventilation. On the contrary, a room may feel fresh and sweet in which, judging by chemical standards, the air is far from pure. There must be some combination of chemical and physical conditions, which accounts for the effect so far as it is objective, but nobody up to the present time has ventured to specify what that combination is.

The future of the sciences of heating and ventilation depends on the analysis of the conditions which produce the feeling of comfort and other effects. The criterion of success is a pleasing effect on the feelings of an individual, but we must, in order to get this subject on a scientific basis, be able to translate the feelings of an individual into terms of measurable physical conditions. The physiologist and hygienist have to specify what are the conditions that will be regarded as healthy and comfortable, and the only legitimate function of the engineer as such is to produce and control such specified conditions; for instance in the matter of heating, the practical problem before the engineer is to introduce heat into a building in such quantity and such form as to make the people comfortable. This can be done *either* by convection currents *or* by radiation, a fact which has received, so far, no proper recognition. Indeed it does not seem even to be generally clearly understood just what is meant by the expression "temperature of the room." Commonly understood, it means the reading of an accurate thermometer suspended in the room, but a thermometer suspended in a room does not indicate the temperature of the room surrounding it, as it is largely influenced by the great amount of radiant energy impinging on the bulb which has no connection with air temperature.

In this connection, the author mentions the fact that a good many people cannot endure radiator heat. It is absurd to believe that it is a "dry" heat, as it is no more dry than any other form of heat. Why then is radiator heat so distasteful to many persons? To answer this question, the author has introduced a conception which he has named "radiant temperature," the idea of which is that temperature which a thermometer would register if there were no air in the room at all, a sort of mean of the temperature of the surrounding walls. There are four differnt quantities—air temperature, radiant temperature, quantity of convected heat and quantity of radiant energy, which must be measured before one can answer the questions which come up in connection with various types of heating, and before that is

done, it is necessary to determine experimentally what is the relation between the thermometer reading, the air temperature and the radiant temperature. The author has devised for this purpose, several instruments of comparatively simple construction. One of them has as its object to ascertain what are the mean temperatures of the surfaces of the walls of the room, the furniture, and of the exposed surfaces, the temperatures of which have an effect on the bulb of the thermometer. The second instrument is for finding the actual temperature of the air. In this apparatus the radiant temperature is artificially made identical with the air temperature so that both are the same as the temperature reading.

The author claims to have proved by the aid of these instruments that the stuffy feeling which is often associated with systems of central heating is due largely, but not entirely, to the fact that the air temperature is too high and the radiant temperature is too low; the freshness of a building depends on keeping the air temperature relatively low and the radiant temperature high. It is the temperature and humidity of the air, which are the important points, and not its chemical freedom from CO_2 or other organic products.

At the University College in the Department of Heating and Ventilating Engineering, an effort is made to develop experimentally the law of pneumatics on a somewhat similar basis to that of electricity. A fundamental formula is taken in a form comparable to the Ohm's law, viz., $H = RQ^2$, and the validity of this law is experimentally tested in all kinds of pneumatic flow. To do this, special apparatus had to be devised, such as a large apparatus, a pneumatic analogue of the Wheatstone bridge, for the determination of specific resistance. This method is of great importance not only for the heating and ventilating engineer but also in many other lines; for example, specifying proper resistance in pneumatic units for a boiler flue or chimney will make it possible to deal on a rational basis with the problem of chimney shafts. By the application of such rules, we can determine what is the actual resistance of a boiler flue and what is the maximum capacity of a plant either in heat units or pounds of steam. To apply the method of power resistance to the determination of resistance of boiler flues and chimney shafts it is only necessary to attach a fan to the air inlet of the boiler through a chamber in which a constant low pressure of air can be maintained. An adjustable resistance between the fan and the boiler inlet is then allowed and the current measured in several cases, from which the pneumatic resistance can at once be established. In fact, it is even possible to determine the value of the resistance without a fan by having a very accurate micrometer gage, as the author shows. (40 pp., 8 figs. *gdA*).

UNIVERSITY OF ILLINOIS

Bulletin, vol. 12, no. 32, April 12, 1915, Urbana, Ill.

A STUDY OF BOILER LOSSES, A. P. Kratz.

Description of experiments undertaken to determine the conditions prerequisite for the continuous operation of the boilers in the new power plant at the University of Illinois and to permit a detailed study of the boiler and furnace losses, under varying conditions of load, depth of fuel bed and draft.

The boiler was operated as one of a battery of two boilers which delivered steam directly into the mains connected with the old plant. It was a Babcock & Wilcox boiler, designed to carry a working pressure of 160 lb. per sq. in. and having two 42 in. by 20.33 ft. drums and 18 sections of 4 in. tubes, 18 ft. long, each section containing 14 tubes. The stokers were of the chain grate type, having an active grate surface of 90 sq. ft. The arch was 15 in. above the grates at the front and 33 in. at the back. The draft was produced by means of a brick chimney 175 ft. high, having an internal diameter of 10 ft. With a few modifications, the methods employed in these experiments were those of the A.S.M.E. Code for conducting boiler trials.

In the items in the tables there are added to those of the boiler test Code of the A.S.M.E., data on three efficiencies, viz., the efficiency of furnace and grate; the efficiency of the furnace, and the efficiency of the boiler exclusive of the furnace and grate. This was done because the efficiencies given in the A.S.M.E. Code are over-all efficiencies for the boiler and furnace together and do not afford a means of determining whether a loss in the efficiency of a unit is due to poor furnace construction, dirty tubes or faults in the boiler itself.

The following conclusions are drawn by the author from his tests: As regards the relation between thickness of fire, capacity and efficiency, it was found that the best efficiency under full load conditions was obtained with a fire of about 7 or 7.5 in., as this seemed to give a fuel bed resistance such that the normal amount of coal can be burned without excessive draft. For each load there seemed to be a well-marked thickness of fire which gave the best efficiency and, as the load decreased, this also became less; thus, for 1.25 load, the maximum efficiency occurred with 8 to 8.5 in. fire; for full load with 7 to 7.5 in. and, for ¾ load, with about 6.5 in.

The over-all efficiencies obtained were not surprisingly high, as under normal conditions of load and fire the over-all efficiencies have been about 65 per cent. The efficiency of the furnace and grate was fairly constant for all loads and depths of fuel bed. The losses in efficiency at higher loads were due to reduced heat absorption by the boiler and, in general, the lower boiler efficiencies coincide with the higher temperatures. As regards the amount of draft necessary, it is determined by three factors: the thickness of the fire, the amount of dust in the coal and the horsepower development. The 9.5 in. fire was found to invariably require the maximum draft for any given load. With thinner fires, sometimes one and sometimes another require more draft, depending largely upon the amount of dust and slightly varying horsepower. Between the limits of 24 to 32 lb. per sq. ft. of grate surface, and with a normal thickness of fire of about 7.5 in., it requires a draft of approximately 0.01 in. of water per lb. of coal per sq. ft. of grate surface per hour to burn Illinois screenings.

The relation between load, combustion and horsepower developed may be represented by a straight line. The percentage of excessive air decreases to a minimum and then increases again as the thickness of the fire increases. With thin fires, there is a marked tendency toward the formation of holes in the fuel bed through which an excessive amount of air can pass. Also, the entire fuel bed is more open and porous. The air is therefore not brought into as intimate contact with the incandescent surface of the coal as it otherwise would be, which leads to an excess of air. For fires less than 7.5 in. thick, the excess air increases when the load or rate of combustion is increased if a constant depth of fuel bed is maintained, while for fires above 7.5 in. thick, the reverse is true (72 pp., 31 figs. *e*).

MEETINGS

MINNESOTA, MAY 10

A joint meeting with the A.I.E.E. was held at the University of Minnesota on May 10 at which Mr. Brillhart of the Minneapolis General Electric Company gave a paper on the Lake Nokomis Electric Dredge and H. F. Teetsell of the Waldorf Box Board Company gave a paper on the Application of Electric Drive to Paper Mills and Data concerning the Paper Industry. Both papers were illustrated with lantern slides.

LOS ANGELES, JUNE 15

A meeting of the Los Angeles Section was held on June 15, it being a joint meeting with the Southern California Section of the A.S.C.E., the Los Angeles Section of the A.I.E.E., the A.S.C.E., the A.I.M.E. and A.S.C., The Southern California Chapter A.I.A. and the Engineers and Architects Association of Los Angeles. The subject of the meeting was Service of the Technical Man to the Community. The meeting was addressed by William Mulholland, Samuel Storrow and James A. B. Sherer.

CINCINNATI, JUNE 24

A joint meeting of the Cincinnati Section, A.S.M.E., and of the Engineers' Club of Cincinnati was held on the evening of June 24, 1915. Instead of the usual paper, a discussion took place on The Relations between the Valuation of Public Utilities and the Determination of Rates. There were three leaders of the discussion.

Mr. J. A. Lilly presented the point of view of the consulting engineer. He gave an impartial resume of the development of the various public service commissions and of the differences in opinion in the methods of physical valuation of properties. He dwelt for some time upon the intangible nature of franchise values and cited a number of cases in which supposedly able and honest engineers varied widely in their estimates of a given property.

Mr. O. F. Shepard presented the point of view of the consumer, who has had engineering training and experience. Mr. Shepard felt that large differences in valuations and contests over rates would occur as long as human nature does not undergo a violent change.

Mr. F. R. Healey presented the point of view of those who have been actively engaged in the operation of public utilities. Mr. Healey contended that time franchises have a value, even at their expiration; that is, that the value of the business as a growing concern is a real asset.

While no local instances were mentioned by the leaders of the discussion, certain public rates that are before the city council gave an added interest to the remarks of various speakers. The meeting was attended by about 100 members and guests.

NECROLOGY

JAMES TAGGART HALSEY

James Taggart Halsey was born in Philadelphia, Pa., in 1854, and was educated at the Episcopal Academy in that city. He was apprenticed in the Pennsylvania Railroad shops at Altoona, following which the railroad placed him in charge of its signals, and he made a number of basic inventions of types of this railroad auxiliary. He resigned from service with the Company to take up a position with the Talbot Works, Richmond, Va., in which he continued for seven years. He later specialized in portable machine tools, maintaining a shop in Philadelphia. He was the inventor of the Halsey Motor Truck for trolley roads; this was a pioneer invention in this field, and one in which several prominent engineers displayed interest.

Mr. Halsey was elected to membership in the Society in 1885. He died in Philadelphia on April 27th, 1915.

JOSEPH AUSTIN HOLMES

Joseph Austin Holmes was born at Laurens, S. C., in 1859. He was educated at Cornell University, from which he was graduated Bachelor of Science in 1881. He became professor of Geology and Natural History at the University of North Carolina in the same year and continued as such until 1891. He was State Geologist from 1891 to 1903. In 1904 he was appointed by President Roosevelt as Chief of the U. S. Geological Survey Laboratories for the testing of fuels and structural materials, rendering noteworthy services. President Taft appointed him in 1910 head of the newly-created U. S. Bureau of Mines, and under his management great progress was made in perfecting methods of saving life in mines. The chief work of the Bureau under his direction has been the investigation of the cause of coal mine explosions, and one of his most important discoveries was that the dust from bituminous coal was more dangerous to miners than firedamp.

He received the degree of Doctor of Science from the University of Pittsburgh, and also of Doctor of Letters from the University of North Carolina, both being conferred upon him in recognition of effort in the mining industry.

He was a member of the American Institute of Mining Engineers, American Society for Testing Materials, the National Conservation Commission, and other organizations.

He was elected to membership in the Society in 1908. He died on July 13, 1915.

THOMAS DYSON WEST

Thomas Dyson West was born in Manchester, England, in 1851, and was the son of a neice of Dr. Michael Faraday. He was brought to America in childhood. At the age of twelve, he began the practical study of engineering at the Portland Locomotive Works, Portland, Me. In 1887, he organized the Thomas D. West Foundry Company, now known as the Valley Mold & Iron Company, of Sharpsville, Pa., and ten years later he founded the West Steel Casting Company. He was vice-president and general manager of the former until 1909, and was chairman of the board of directors of the latter until the time of his death.

Mr. West was the author of many books and papers on practical foundry work, publications which were basic in foundry literature and included "American Foundry Practice," "Moulders' Text Book," etc.

He established and used American Foundrymen's Standardized Drillings, which was taken over by the U. S. Bureau of Standardization in 1905. He was also the pioneer of the Safety First movement, and he organized the American Anti-Accident Society.

He was a member of the American Society for Testing Materials and was president of the American Foundrymen's Association in 1905-6. He was elected to membership in the

Society in 1884, and he died in Cleveland, Ohio, on June 18, 1915, from injuries received in an accident.

AUSTIN LORD BOWMAN

Austin Lord Bowman was born in Manchester, N. H., in 1861. He studied engineering at Yale University, and was graduated with the degree of Bachelor of Arts in 1883. For four years he specialized in construction and bridge work for western railroads, and in 1887, he came East and took up similar work with the Norfolk & Western Railroad. From 1890-1895 he was engineer and superintendent of construction for the American Bridge & Iron Company, Roanoke, Va. In 1897, he established himself in New York City as a consulting engineer on heavy railroad work. For six years, beginning 1901, he was consulting bridge engineer for the Central Railroad of New Jersey, reconstructing most of the important bridges on that road. In December 1907 he became consulting engineer of the Department of Bridges of New York City, and last summer was made chief engineer of the Department, a position which he retained until his death.

Mr. Bowman was a member of the American Society for Testing Materials, American Railway Engineering & Maintenance of Way Association, and the New York Railroad Club. He was a member of the American Society of Civil Engineers and a director from 1905-1907. He was elected to membership in the Society in 1899. He died on June 3, 1915.

PERSONALS

Maynard D. Church has accepted the position of assistant engineer of the Terry Steam Turbine Company of Hartford, Conn. He was until recently associated with the Dayton Turbine Pump Company, Cleveland, O., in the capacity of chief engineer.

Alfred J. Ormston, Jr., has accepted a position with the Jones & Laughlin Steel Company, Woodlawn, Pa., in the steam engineering department.

Alfred C. Brown, for the past four years general supervisor of equipment with the Edison Lamp Works of the General Electric Company, Harrison, N. J., has accepted the position of works manager with The Hopkins and Allen Arms Company of Massachusetts, factory located at Norwich, Conn.

F. H. Newell, consulting engineer U. S. Reclamation Service (Director 1907-1914, Chief Engineer, 1902-1907), has accepted the position of head of the civil engineering department of the University of Illinois, Urbana, Ill.

Lawrence B. Webster has completed his duties as engineer for the Committee on Appraisals of the Ohio Electric Light Association and has severed his connection with the American Gas and Electric Company of New York. He is now associated with Mandelbaum, Wolf and Lang, Cleveland, Ohio, managers of public utility and mining properties.

Richard C. Collins until recently connected with the United Shoe Machinery Company, Beverly, Mass., as mechanical engineer, is now associated with the Chelsea Fibre Mills, Brooklyn, N. Y., in the capacity of mechanical superintendent.

William H. C. Ramsey has accepted the position of general manager of The York Water Company, York, Pa. He was until recently associated with the Johnstown Water Company, Johnstown, Pa., in the capacity of superintendent.

Alfred S. Richardson has just completed a hydroaeroplane, of his own invention, which weighs 2300 lb. and has 2 six-cylinder Emerson engines of 68 actual h.p. each. The machine is the largest of its kind ever constructed and has two sets of planes, arranged in tandem, on each side.

The University of Toronto has recently conferred the new degree of D.Sc. upon T. Kennard Thomson. It is the first official recognition that the University of Toronto has shown a man in the engineering profession.

STUDENT BRANCHES

CORNELL UNIVERSITY

At a meeting of the Cornell University Student Branch on June 28, the following officers were elected for the following year: A. R. Cota, president; W. H. Rice, vice-president; W. F. Courtney, secretary and W. W. Robertson, treasurer.

KANSAS UNIVERSITY

The last meeting of the year of the Kansas University Student Branch was held on May 20 at the home of Prof. A. H. Sluss. The following officers for the coming year were elected: Jerry Stillwell, president; Burnette Bower, vice-president; A. J. Nigg, corresponding secretary; Charles Hagenbuch, recording secretary; Walter Pickering, treasurer; G. A. Rathert, chairman of the Program Committee; and Jerry Stillwell and S. E. Campbell, representatives on the Governing Board of Associated Engineering Societies.

STATE UNIVERSITY OF IOWA

The following officers have been elected for the coming year by the State University of Iowa Student Branch: C. W. Harrison, chairman; Max Kalen, vice-chairman and Victor Johnson, secretary and treasurer.

EMPLOYMENT BULLETIN

The Secretary considers it a special obligation and pleasant duty to be the medium of assisting members to secure positions, and is pleased to receive requests both for positions and for men. Copy for the Bulletin must be in hand before the 18th of the month.

POSITIONS AVAILABLE

The Society acts only as a "clearing house" in these matters and is not responsible where firms do not answer. In sending applications stamps should be enclosed for forwarding.

07 Chief draftsman to take charge of engineering department of St. Louis concern; man of sufficient ability and commercial experience to make success of the position; executive, with fundamental training in practical mechanical work of modern drawing office, machine shop, pattern shop and foundry practice, but must be commercial executive.

030 Agency wanted for small patented electrical device of foreign invention. Apply by number.

068 Young Engineer to take charge of tool department of Massachusetts concern manufacturing sterling silver hollow ware; one who understands machine shop practice generally, but more particularly a man familiar with up-to-date methods of working sheet metal, such as rolling, cupping, drawing and spinning; will have charge of laying out the tools to manufacture the goods, supervise the making and operation of the tools; knowledge of up-to-date methods of shop practice of advantage. Position has a good future for the right man.

069 Steam specialty salesmen who desire to take on a line of vacuum heating specialties can arrange for representing manufacturer. Representatives wanted in several leading cities. Apply through Society.

0101 Large manufacturing concern wishes to engage as employment head a man of special ability in the selection of labor; would be permanently located at the factory and should be able to select men of proper character, who would have the training for the work carried on in the various departments. State age, experience in full and salary wanted. Location Philadelphia. Name confidential.

0108 Head superintendent, for large European concern thoroughly posted in the manufacturing of rubber shoes, technical and surgical articles, covering for rollers, tubes of all kinds, balls, toys and similar articles to be made of hard or other rubber, etc. Apply by letter.

0116 Man who has had practical mechanical engineering education, with knowledge of electrical engineering, machine shop work, drafting, etc., desires technically educated assistant in the further development of plans for constructing an improved rock tunneling machine. Location New York.

0136 Good opportunity for first class designers; men with drawing office experience needed, particularly on heavy machine tools and similar machinery. Location, Pennsylvania.

0171 Competent designer for cane sugar machinery for large manufacturing concern. None but thoroughly experienced men need apply. State age, experience and salary expected. Give references. Location New York.

0172 Assistant works manager for Michigan firm manufacturing cranes and electrical specialties. Applicant must be high grade in ability and personality, with experience in structural, mechanical and electrical work and modern manufacturing methods. Name confidential.

0174 Capable man to take charge of manufacturing department of Massachusetts concern. Experience not expected in particular line of work, which is the manufacture of spectacles and eyeglasses, but some manufacturing experience required on small accurate work. Applicant must show that he has ability to handle men and get results at a fair cost. Salary $1800 per year. Apply by letter.

0176 Power transmission salesman for New York concern manufacturing pulleys, shaft-couplings, collars, etc.

0177 Engineering draftsman who can handle general power plant work. Technical school man who has had three or four years experience in an engineering office. Location New Jersey.

0180 Firm of constructing engineers desires to add to its staff several good mechanical and electrical engineers. Location New England. Name confidential.

0181 Shop superintendent experienced in deep drawing of brass wanted for concern in New York State. Apply by letter.

0184 Superintendent of a shop employing one hundred and fifty men in the forging of steel tools; will have complete charge of the manufacturing and labor and should be able to plan and lay out new work. Initial salary $2000 to $2500. Subsequent figure will depend entirely upon results obtained. Location East. Apply by letter. Name confidential.

0188 Chief draftsman on steam or gas engineering. Location Jersey City, N. J.

0189 Draftsman for industrial and power plant, layout of machinery and structural building design. American. Salary $150 a month. Location Pennsylvania. Name confidential. Apply by letter.

0190 Foreman for European concern (listed in 0108) manufacturing articles of hard or other rubber. Apply by letter.

0192 Production Engineer or mechanical superintendent for pulp mill; man with technical training and practical experience; one who is familiar with modern methods of machine shop management. Name confidential. Apply by letter.

0195 Assistant Professor in department of mechanical engineering. Salary $1500. To teach Machine Design and allied subjects. Must have completed a course in mechanical engineering; some practical experience as well as successful teaching experience. Location Texas.

0197—Wanted—Engineer, assistant required for large maintenance department experience, along lines of power station work, millwright and piping, drafting and cost estimating. Position pays $20 to $25. Location Massachusetts. Replies must be written on one page and confine answer to the following: name; age; nationality; education; experience; references.

0198 Instructor in mechanical laboratory work. Salary $1,000 for the college year, with prospects of some increase if engagement is renewed at the end of the year. One who has had some teaching experience in the line indicated. Location Middle West.

0199 Young refrigerating engineer, preferably one who has had some experience in the field, as a salesman and a general man with engineering knowledge to call and talk things over with customers; until the man's ability has been proved, salary ranging about $25 per week. Location Ohio.

MEN AVAILABLE

The published notices of "men available" are made up from members of the Society. Notices are not repeated in consecutive issues of the Bulletin. Names and records are kept on the office list three months, and at the end of such period if desired must be renewed.

H-206 Junior member, mechanical graduate 1907, experienced in advertising and publication work, is open for position as publicity agent or advertising manager. Moderate salary at beginning if position is desirable otherwise.

H-207 Mechanical engineer, well qualified by technical education, experienced in research along lines of engineering physics, desires position involving industrial research or experimental engineering. Would also consider position as salesman on the road.

H-208 Member, mechanical and electrical engineer, formerly U. S. navy inspector, eleven years experience in design and construction of power and industrial plants, testing machinery, technical writing, desires change, preferably with New York consulting engineer or contractor. At present employed.

H-209 Member, age 42, graduate of Stevens Institute of Technology, 1893, with fifteen years general experience, from draftsman up through executive management, followed by seven years specializing in organization and efficiency work in both manufacturing and commercial ends in a wide variety of lines, including manufacture of chocolate, machine shop, underwear, wholesale news distribution, brass goods, foundry, paper boxes, printing and publishing, to avoid continual traveling, desires a permanent connection with a progressive concern, location preferred New York or vicinity. Will invest if conditions are favorable. Available about October 1st.

H-210 Member, Cornell graduate, age 31, married, eight years experience in refrigerating engineering, design and supervision of heat, light and power plants, desires position with consulting engineer or with private firm.

H-211 Member, who has specialized in elevator and hoisting machinery, including motor and control, also conveying and handling machinery and the special structure required in this line, experienced in drafting room, shop, field and estimating, desires position as executive or sales engineer. Can take up sales proposition with technical or non-technical customers and see the work through to completion.

H-212 Member, mechanical and electrical engineer, twelve years experience as combustion engineer, power house tester,

chief electrician and mechanic, desires position. Location immaterial. Speaks Spanish fluently.

H-213 Student member, 1915 graduate of Columbia University, in mechanical engineering, desires a position in or around New York which offers an opportunity to start in the engineering profession. Salary secondary consideration.

H-214 Junior, power and designing engineer, seven years practical experience in power plant design and operation, heating, ventilating, electric light and power, refrigeration, fire protection, reports, plans and specifications, desires position.

H-215 Member, graduate M.E., age 35, ten years in an executive position as technical writer and correspondent of technical subjects of a consulting engineering nature, teaching experience, also experience as practical machinist. At present employed, but open for engagement.

H-216 Junior member, M.E., five years experience in design and manufacture of stationary oil engines, two years experience in power plant work and general equipment, desires position with consulting engineer. Will consider any opening which may lead to responsible position. Location immaterial.

H-217 Graduate, Massachusetts Institute of Technology, successful in organizing in both production and business departments, is qualified to assume responsibilities of manager or assistant in plant where special executive capacity and manufacturing experience are required.

H-218 Technical graduate, age 33, ten years experience in boiler manufacture and general plate work, desires position as manager or assistant manager. At present employed.

H-219 Associate-member, age 27, Stevens graduate, six years experience in gas engine, designing, experimental, testing, and every department of machine shop, desires position as assistant to executive or other responsibility.

H-220 Associate-member, Cornell M.E., age 32, four years experience steam and efficiency engineering, one and one half years as master mechanic, capable of handling men, now holding manufacturing executive position, desires chance for more rapid advancement.

H-221 Student member, technical man, Purdue University, age 26, engineering experience, with initiative and executive ability, desires position as sales engineer or assistant to chief engineer. Location middle West preferred.

H-222 Associate-member, technical graduate, nine years practical experience in foundry, machine shop and assembling work; time study and time setting for prominent machine tool manufacturer, now employed traveling as high speed expert and adviser, desires position as superintendent or similar executive where opportunity is offered to acquire an interest in the business. Location preferred middle West.

H-223 Mechanical engineer, five years practical experience in steam turbines, power plant equipment, and layouts, also construction work and reinforced concrete, desires permanent position. At present employed.

H-224 Junior member, Stevens graduate, desires to associate with engineering firm or patent attorney. Opportunity for future considered before salary.

H-225 Junior member, age 27, graduate in mechanical engineering, three years experience in testing and operation of power plants, several years in editorial and office work, desires position as secretary or assistant to manager. At present employed. Location preferred New York.

H-226 Student member, 1914 M.E. graduate, desires position in engineering or experimental department of company manufacturing corn harvesting machinery or other agricultural implements. Location preferred middle West. At present employed in gas tractor company.

H-227 M.E. specialized on combustion of soft coal, has had experience as machinist, draftsman, engineer of coke works and chief engineer of large manufacturing concern, desires position with boiler, stoker or furnace manufacturer.

H-228 Student member, 1915 M.E. graduate, two years accounting experience, also field work on dredging machinery, drafting and salesman, desires position with manufacturing concern with chance for advancement. Location preferred New York or New England states.

H-229 Member, age 33, twelve years experience, six years with present company, is seeking position with opportunity for advancement, as mechanical engineer or charge of drafting room. Has good designing ability.

H-230 Member, graduate engineer, age 35, American, capable designer, practical foundry and shop man, experienced in modern production methods and management, has had broad engineering experience in Europe and America as mechanic and executive in design and manufacture of engines, heavy machinery, machine tools, automatic machinery and light high grade specialties, desires position as chief engineer, superintendent, manager or assistant. Location immaterial, salary commensurate with position.

H-231 Graduate M.E., at present employed as sales engineer and designer in heating and ventilation and power plant lines, thoroughly acquainted with vacuum heating systems, desires position in the same or along similar lines.

H-232 Graduate mechanical engineer, age 28, five years practical work prior to college course and two years subsequent thereto, wishes a teaching position in Eastern or Southern college or university in experimental engineering, mechanics or physics.

H-233 Japanese member, graduate of electrical and mechanical school in 1903, connected with telephone and railroad companies of New York City, intending to visit Japan next autumn, wishes to communicate with American firms planning to develop their business in Japan or China. Will consider agencies or commission. First class references will be furnished responsible parties interested.

H-234 Member, age 45, designing engineer and master mechanic, American, speaking French and German, desires position. South preferred. At present employed.

H-235 Member, with an unusually thorough experience in manufacture, and first class record as executive, at present in successful consulting practice in scientific management, and especially successful in developing capable men, desires manufacturing executive position.

H-236 Superintendent, twenty years mechanical and executive experience on small interchangeable work, competent to design tools and fixtures for increasing production and reducing costs. At present employed.

H-237 Member, age 33, married, graduate of the United States Naval Academy, several years active service in the United States Navy, desires operating executive position with manufacturer of arms and ammunition. Salary $4,000. Location immaterial. At present employed.

H-238 Junior member, Columbia graduate M.E., 1913, two years experience in production and drafting departments, desires position in New York with chance for advancement. At present employed.

H-239 Member, in consulting practice, with broad experience in perfecting general organization of manufacturing companies and in efficient operation of plants, including familiarity with various processes of manufacture, particularly metal working, is open for temporary or permanent connection. Under suitable conditions will take stock or interest in profits as part compensation for services.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A.I.E.E. and A.I.M.E. can be secured on request from Calvin W. Rice, Secretary of Am. Soc. M. E.

CARNEGIE ENDOWMENT FOR INTERNATIONAL PEACE. Pamphlet nos. 4-20. *Washington, 1915.* Gift of Carnegie Endowment for International Peace.

CHICAGO RAILWAY TERMINAL COMMISSION. Preliminary Report submitted to City Council Committee on Railway Terminals, March 29, 1915. Gift of John F. Wallace.

CHICAGO TRACTION. Board of Supervising Engineers. 6th Annual Report, 1913. *Chicago, 1915.* Gift of Bion J. Arnold.

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[1] A complete list of the officers and committees of the Society will be found in the Year Book for 1915, and in the January and July 1915 issues of The Journal